The NEW NATURAL HISTORY

Third Volume

J. ARTHUR THOMSON

Specially drawn for this work by J. E. Waters.

HERMIT CRABS (*Eupagurus bernhardus*) FIGHTING.

The soft and sensitive tail of the Hermit Crab is sheltered within the borrowed shell of some Gastropod or sea-snail, such as the large whelk Buccinum. This protection allows the hermit crabs to indulge their combative tendencies, the significance of which is obscure. In the encounters the combatants grip one another with their forceps and there is sometimes a serious breakage

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PROFESSOR
J. ARTHUR THOMSON

VOLUME [illegible]

G. P. PUTNAM'S SONS
NEW YORK and LONDON
1926

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BY

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LX
ANIMALS OF THE SEA

IT is highly probable that the first really successful living creatures lived in the primeval seas that were formed after the earth's crust cooled. Perhaps they were able to feed, as green plants do, by utilising some of the energy of sunlight to build up carbon-compounds out of carbonic acid gas and water. They were probably free-swimming units of living matter, somewhat like the simplest of the minute green Infusorians which are found to-day in large numbers in the open ocean. It is likely that they were, to begin with, very short-lived—perhaps creatures of a day, growing in the sunshine, multiplying in the evening, and dying in the night.

When bucklings of the outer part of the earth's crust led to the establishment of continents, another great step may have been taken. In the inshore waters, shallow enough to be well-lighted, some of the primeval forms of life may have begun to anchor themselves on the rocks, growing out into green threads and plates—beginning the great race of fixed seaweeds or Algæ.

But from among these there probably emerged a new kind of life—minute predatory creatures that fed not on air and water, but on the seaweeds and their fragments, and by and by on one another. They stole the plant's munitions and exploded them. They were *the first animals*, and it is very unlikely that their appearance could be *less* remote than five hundred millions of years ago. About these beginnings we must speak very guardedly, for certainties are few and far between, but all naturalists are agreed that the animals of the sea began from very simple and minute forms of life. It is also probable that there were many millions of years of slow progress in the sea before the freshwaters began to be colonised. Thus if we take the two lowest groups of many-celled animals, the Sponges and the Stinging Animals, we find one family of freshwater sponges and scores in the sea, perhaps a dozen kinds of freshwater polyps and medusoids and thousands of kinds in the sea. This practically proves that these two large groups had a marine origin, and the same conclusion holds in many other cases. We must therefore think of the sea as a great cradle of animal life, and also as a great school. Before giving some particular instances of marine animals, we wish to say a little about the conditions of life in each of the three great haunts which the sea includes. These are (1) the shore of the sea, (2) the open sea, and (3) the depths of the sea. More technically we speak of the littoral, the pelagic, and the abyssal faunas.

The Shore of the Sea.

The shore or littoral area includes the whole of the comparatively shallow, well-lighted, seaweed-growing area round the margin of a continent, or of an island that once was part of a continent. It is peopled by a very large and very representative fauna. Let us run down the list of classes:—Mammals represented by seals, birds represented by gulls, reptiles by the unique giant lizard of the Galapagos Islands, amphibians by the also unique frogs on the Manilla shore, fishes by gunnels and father-lashers, sea-squirts in large numbers, molluscs represented by octopus, dog-whelk, and mussel, crustaceans by hermit-crabs, worms almost innumerable, Echinoderms represented by starfishes and sea-urchins, numerous stinging animals like sea-anemones, sea-fans, and zoophytes, numerous sponges like the Bath Sponge, and then a large contingent of almost microscopic or quite microscopic single-celled animals or Protozoa. The shore roll-call would take a long time.

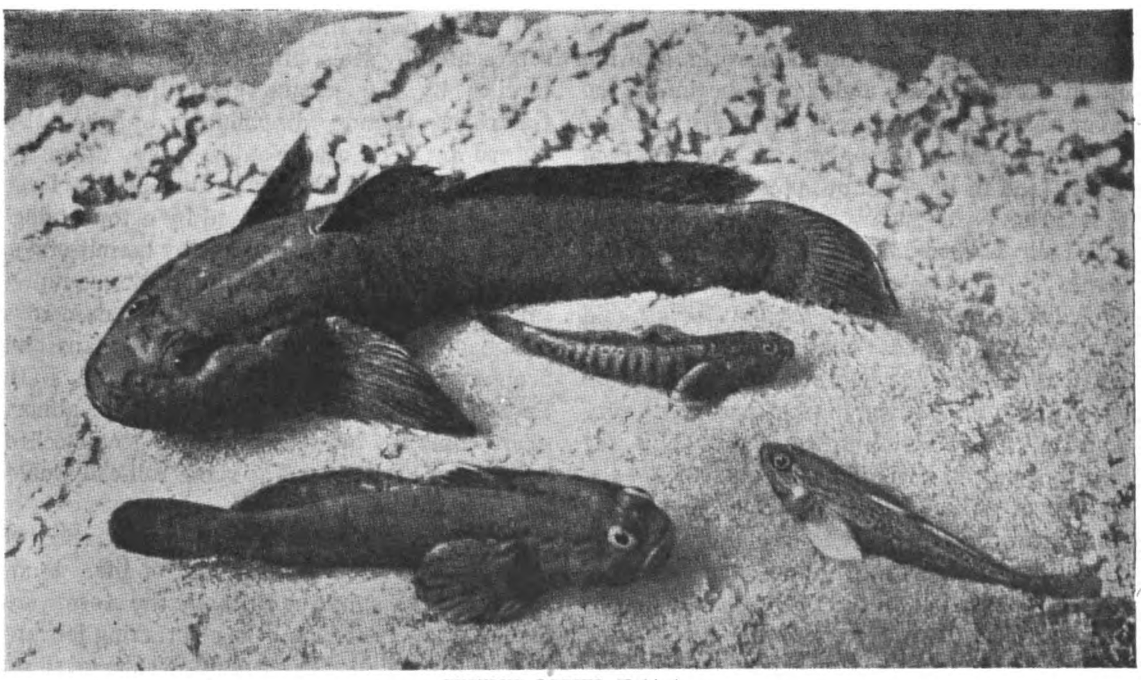
What marks the shore is its combination of difficulties. It is a hard school of life. Difficulties are raised by the tides, by the storms, by the freshwater floods, by the smothering jetsam, by the driven and shifting sand, by the grinding of stones. There is much struggle—for food, which tends to be swept out to sea, for standing-room, and for oxygen. There is struggle against

the risks of dislodgment, smothering, and drought, and against the appetite of enemies. The shore is an arena in which to study not only the struggle between fellows, but the answers-back that animals make to the thrusts and arrows of an outrageous physical environment. The shore abounds in illustrations of " shifts for a living," such as " masking," and peculiar life-saving fitnesses like protective colouration. On the other hand, the shore is rich in examples of devices and arrangements that are not self-regarding, but serve to secure the welfare of the offspring. We must think of the shore as a school of life where lessons have been learned for untold ages, and where good qualities became engrained in many a race of animals. What were these good qualities? " They included the quality of holding tight, which leads on to *endurance*; the quality of biding their time—even till the tide comes in—which leads on to *patience*; the quality of push, which leads on to *endeavour*; and the quality of seizing a good opportunity, which leads on to alertness and power of initiative " (Thomson, "Haunts of Life," 1921, p. 63).

Very different from the shore-area is the open sea, the pelagic realm. It includes all the well-lighted surface zones well away from the shallow shelf where the fixed seaweeds grow and where the water is often thick with fine particles in suspension. Unlike the shore the open sea has almost limitless room, very abundant floating food, and great uniformity of physical conditions. The pelagic animals live, as usual, to some extent on one another, but they depend fundamentally on the floating sea-meadows of simple Algæ which sometimes make the sea " as thick as soup."

The Open Sea.

Let us call the roll from below upwards, taking representatives of the different classes. There are the Night-Light Infusorians (Noctiluca) that make the summer seas luminescent, and there are many chalk-forming Globigerinids; there are jellyfishes and Portuguese-men-of-war virulently stinging; there are transparent " arrow worms " and other worms, all sorts of active crustaceans, a family of insects (the sea-skimmers), and such delicately built molluscs as the sea-butterflies and the Argonaut. Just across the borderline separating the backboneless from the backboned, there are free-swimming members of the sea-squirt class, such as the Fire-Flame



BRITISH GOBIES (Gobius).

Gobies occur in all seas except Arctic and Antarctic, and there are also freshwater forms widely distributed. They are mostly carnivorous and small in size, indeed the minute *Mistichthys luzonensis* is only about half an inch long, and is believed to be the smallest of known Vertebrates. Some of the British Gobies are common on the shore and are interesting in their breeding habits. The male mounts guard over the eggs which are laid under a stone or shell or in a sort of nest.

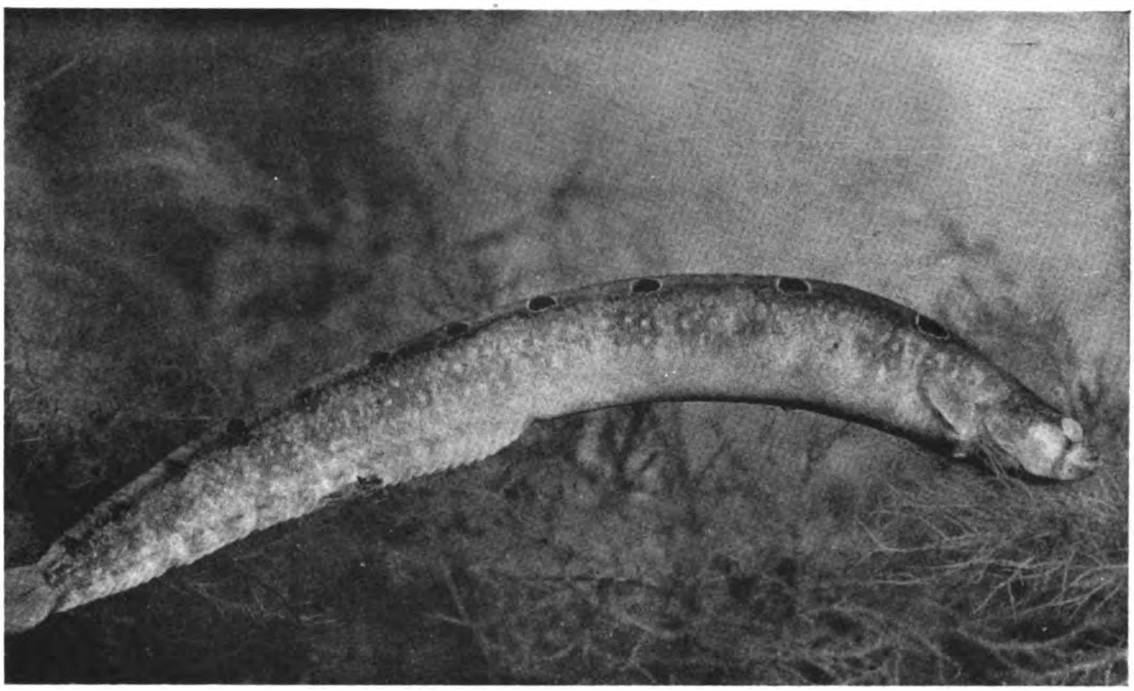


Photo: W. S. Berridge, F.Z.S.

GUNNEL OR BUTTER-FISH (*Pholis gunnellus*).

This slippery fish, often found in shore-pools, deserves its name of Butter-fish, for it escapes through one's fingers in an extraordinary way. It is well adapted to making its way among loose stones and through narrow crevices. The female rolls the eggs into a little ball, puts them into a hole in the rock, and coils herself round them as if she were brooding.

and the Salps. Then there are open-sea fishes like mackerel and flying gurnard, open-sea reptiles like the loggerhead turtle, open-sea birds like the storm-petrel, and open-sea mammals like the whales. It is important to distinguish two very different modes of life—that of the energetic swimmers or Nekton, and that of the easy-going drifters or Plankton.

For the drifters it is important to be lightly built and to have a great capacity for flotation. Thus there may be long delicate processes that project into the water and make sinking almost impossible; or there may be reservoirs containing gas; or there may be accumulations of light fat or oil; or the specific gravity of the animal may be about the same as that of sea-water. The open sea is a safe cradle for young life, especially when there is a power of sinking below the surface when "white horses" appear, but there are some fine examples of arrangements that secure the safety of the young. One of the most beautiful is the cradle-shell made by the female Argonaut or Paper Nautilus. And here it must be remembered that the young stages of many shore animals, such as shore-crab and sand-star, are found in the relatively safe nursery of the open sea, often far from their birthplace and from their future home.

In many ways the strangest of all the haunts of life is the deep sea, by which naturalists mean the floor of the great abysses and the layers of dark water near the floor. It is separated from the pelagic haunt by what are sometimes called the mid-waters, say between 250 and 500 fathoms, where light-rays are practically, yet not quite, absent. Not very much is yet known in regard to the animals of the mid-waters, but there seems to be a distinctive population. There are the mid-water angler-fishes, for instance—sluggish, dark-coloured creatures that seem to attract other fishes by means of a luminous lure. In three of these mid-water Anglers the males are dwarfs and are carried about closely attached by their snouts to the larger females. In two cases the attachment is so close that the blood-vessels of the male's snout join those of the female's skin, and that is how the male is nourished!

The Deep Sea.

The deep sea in the strict sense occupies more than a half of the surface of the globe, and it includes "deeps" that would engulf Mount Everest and show nothing of the mountain

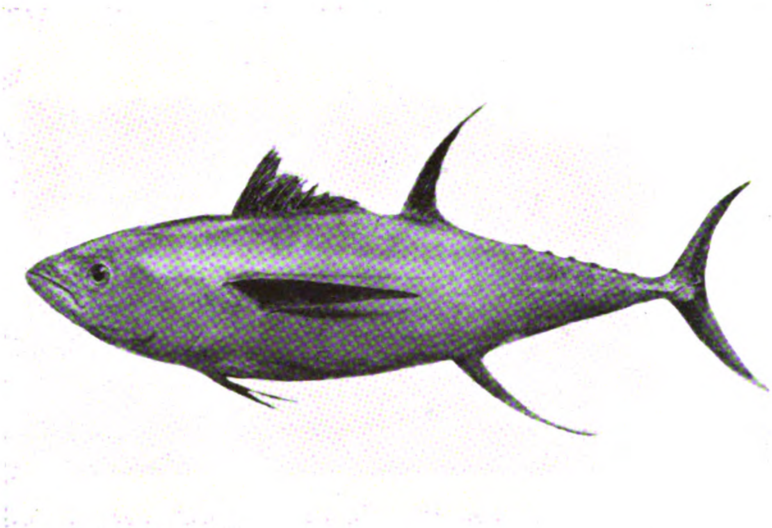


Photo: W. S. Berridge, F.Z.S.

TUNNY OR ALBACORE (*Thunnus thynnus*).

The largest of the mackerel family, reaching a length of ten feet, found in the Atlantic, Pacific, and Indian Oceans, an important food-fish in France and Italy. It devours other fish and is in turn preyed upon by the Killer Whale. It is a swift swimmer and is said to be "warm-blooded."

protruding. The "Swire deep," off Mindanoa, is actually over six miles in depth. There is necessarily enormous pressure owing to the immense weight of water—two and a half tons on the square inch at 2,500 fathoms. There is eternal winter, with a temperature varying but little on each side of the freezing-point of fresh water. There is eternal night relieved only by the fitful gleams of "phosphorescent" light. There is absolute calm and silence. There is no scenery, but a succession of dreary undulations like those of sand-dunes. What an eerie picture this—a deep, dark, cold, calm, silent, monotonous, and plantless world!

But there is no depth-limit to the distribution of animal life, and the abyssal fauna includes simple microscopic creatures—Foraminifers and Radiolarians; many horny and flinty (but no calcareous) sponges; sea-anemones and corals; worms of many kinds in abundance; starfishes, brittle-stars, sea-urchins, sea-cucumbers, and many sea-lilies; numerous crustaceans and quaint creatures called sea-spiders; lamp-shells and moss-animals; all sorts of molluscs; degenerate sea-squirts; and strange fishes, often luminous.

Many deep-sea animals have long stalks raising them up out of the treacherous, smothering "ooze." Others that prowl about have greatly elongated, delicate, stilt-like legs. There is in many cases an exquisite tactility, for in a world of darkness, where sight counts for little, touch becomes a very important sense. Another fitness is the delicacy of build associated with the permeability of the body with water. This circumvents the great pressure, for when the water gets through and through an animal the pressure inside and the pressure outside are equal. It seems likely that the bulk of the fauna of the Deep Sea was established in comparatively recent times, and that it owes its origin to migrants from the shore-area, which followed the down-drifting food and sea-dust. The fauna is more abundant at 2,000 fathoms than deeper down, and it

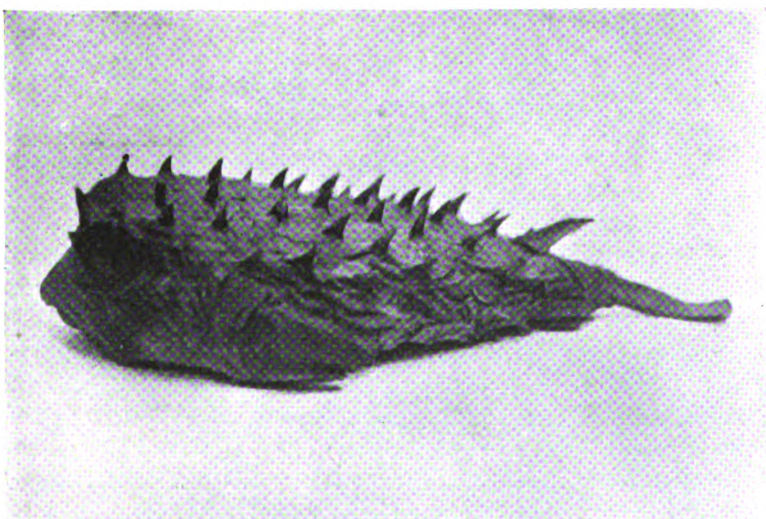


Photo: W. S. Berridge, F.Z.S.

BURR-FISH (*Chilomyterus spinosus*).

In some Bony Fishes, such as the Porcupine Fish or Diodons, the ordinary scales are prolonged into hard erectile spines, like those shown in this photograph, which form a very effective armour.

varies considerably according to the nature of the fine deposits that form the ooze. But there is no "deep" without its tenants, and it is noteworthy that in this remote world of darkness there is the same order, the same fitness, the same finished perfection, and the same beauty that we find everywhere else.

So much for the general conditions of marine life in each of the three great haunts. Let us now consider a number of representative types.

Shore-Crabs

Some animals are safe because of their armour—hedgehogs, for instance—but have little in the way of weapons. Others are safe because of their weapons—cuttlefish, for instance, with their grappling arms and parrot-beak-like jaws—but have little in the way of armour. But crabs illustrate an admirable combination of offensive and defensive equipment. Their forceps or great claws are effective weapons, giving a shrewd nip; their shell of lime and chitin is effective armour. They have their enemies, such as cuttlefishes, but their foothold in the struggle for existence is very secure. The seashore is no place for the ungirt loin, no place for "slackers," and we get a glimpse of the keenness and subtlety of the struggle for existence when we notice how crabs, well-equipped as they are, add to their security of tenure by many inventions.

In the case of the common shore-crab (*Carcinus mænas*) we often find in the young stages a remarkable harmony of colour between the shell of the animal and the surface on which it creeps. According to the nature of the rocks and the encrusting calcareous Algæ that grow on them, different shore-pools have different hues—reddish, greenish, greyish, and so on; and the young crabs, no bigger than the nail of our little finger, that live in those pools, often defy detection. Until they move they are part of the scenery of the pool, and we do not see them easily even when we stoop down and stare. The exact manner of the colour-change is not as yet very clear.

It must be understood that the small, yet fully formed, crabs we catch on the shore, and return to their pools, have a long history behind them. The eggs which the mother-crab carries about underneath her tail hatch out into pin-head larvæ which are swept out into open waters. They are too delicate for the rough-and-tumble life among the rocks. They pass from stage to stage, and when they have at length become miniature crabs, they cease to be surface-swimmers, and creep up the slope on to the shore.

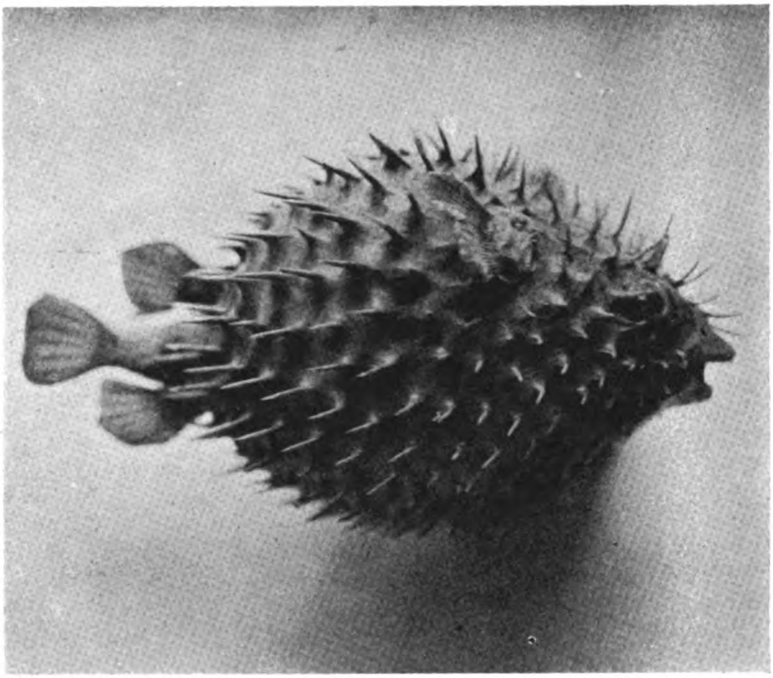
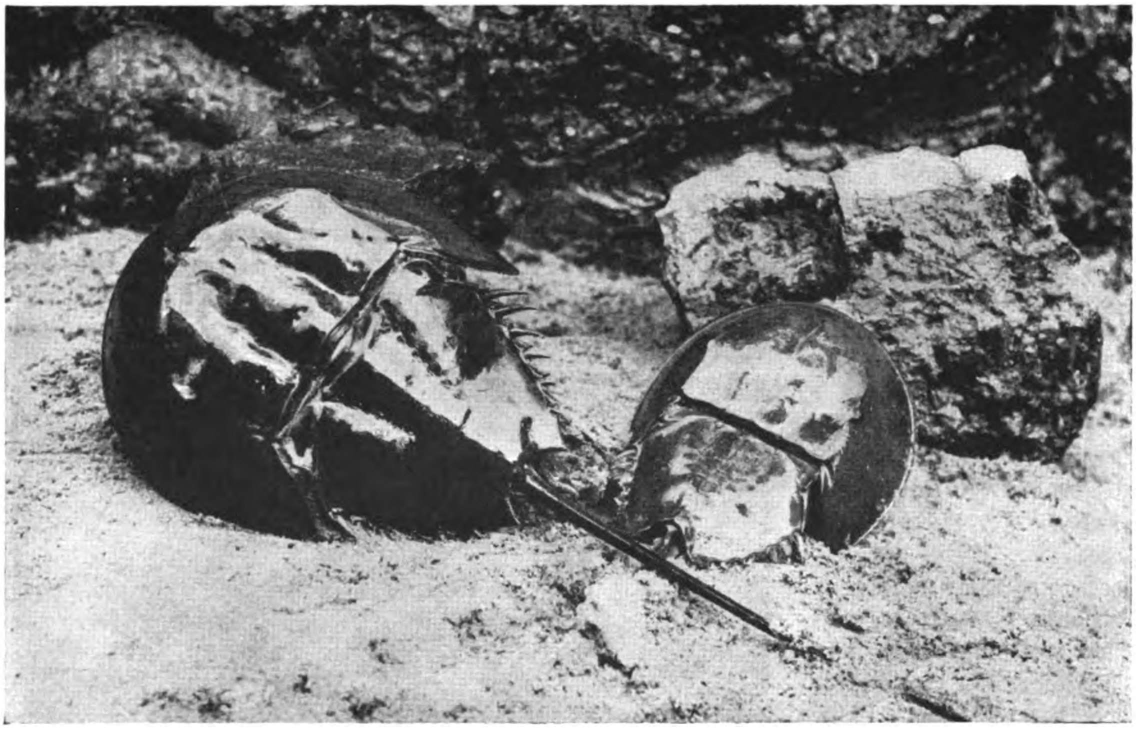


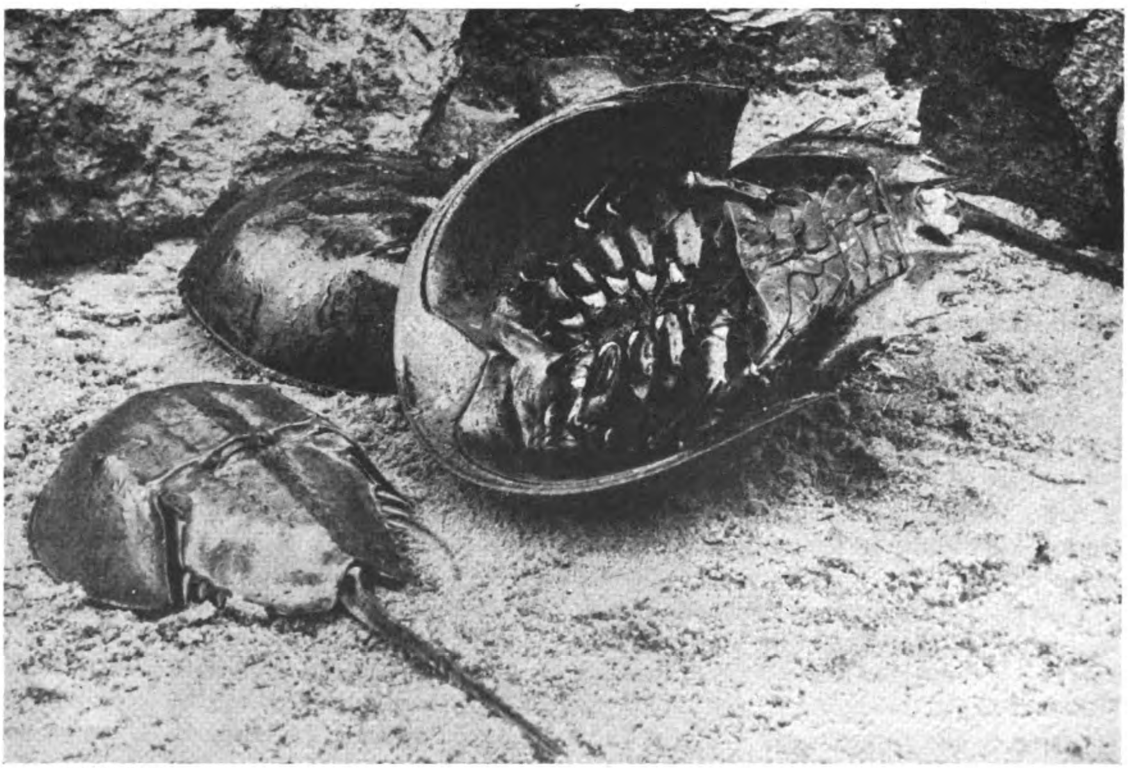
Photo: W. S. Berridge, F.Z.S.

GLOBE-FISH (*Diodon maculatus*).

This kind of Globe-Fish or "Porcupine Fish" is found in Tropical seas. It is covered with movable spines, and it can inflate its belly with air. Being well protected, it lives a leisurely life, often floating near the surface.

In the case of the Sand-crab (*Hyas araneus*) and the Narrow-Beaked Crab, we often see what is called "masking" or disguise. It tempts one to think generously of the crab's brain. The creature takes pieces of seaweed, nibbles at them a little, and then rubs them on the back of the shell, where they catch on tiny bristles. Thus





Photos : F. W. Bond.

THE KING CRAB (*Limulus polyphemus*).

These quaint animals, sole survivors of an ancient race of jointed-footed animals, are usually regarded as distant relatives of scorpions and other Arachnids. They burrow in the sand on the coasts of North America, Japan, China, and the East Indies, preferring water of two to six fathoms, and feeding mainly on worms, but partly on bivalves. At night they leave the sand and move about by a series of "short swimming hops," balancing for a moment between two hops on the tip of the tail-spine. The lower picture shows the underside of one of the crabs.

the crab practises the "Walking Wood of Birnam" trick, and goes about well-disguised with a little garden on its back. Sometimes it uses pieces of sponge and zoophytes and other animals, always cloaking its reputation, for the crab must have something corresponding to a reputation on the seashore. In an aquarium, crabs sometimes put on a garment which makes them more conspicuous, such as pieces of brightly coloured silk which are given to them to play with. They have to obey the instinct to cover themselves, and we must not make too much of the fact that in quite artificial conditions their instinct sometimes leads them astray.

A common accident on the seashore is that an animal gets pinned down by the dislodgment of a stone. This sometimes happens to a starfish, which may then escape death by surrendering an arm. The crab in the same way has organically learned the lesson that it is better that one member should perish than that the whole life be lost. When a shore-crab or an edible crab gets a leg badly bruised, it presses the tip against a stone or against its own shell, and then breaks it off. In the swimming-crab and the sand-crab no *point d'appui* is required for the self-amputation. What is it that happens? Across the second joint at the base of the limb there is a preformed line of weakness, and the breakage is due to the very forcible contraction of antagonistic muscles. This is neat surgery, but the touch of perfection is to be found in the stump of the limb where two prearranged membranous flaps fold together when the breakage occurs. This bandage prevents bleeding, and it also forms a scar under which a new leg can be grown in miniature—to be shot out by-and-by like a jack-in-the-box. But we must not think of the crab practising clever surgery on itself. Whatever be the history of the neat device, it is now of the nature of an ingrained reflex, similar to our involuntary withdrawal of our finger from an over-heated plate.

The crabs on the shore do not flaunt themselves, but their elusiveness is rather to secure good hunting than because of personal risks. When full grown they have an air of competence and confidence; they show fight when attacked; they are successful beasts of prey. But there is a recurrent crisis that taxes their resources, and that is moulting. All these well-armoured jointed-footed animals have to cast their shell periodically, as long as they go on growing. As there is no life in the shell, it cannot expand as the animal grows bigger.

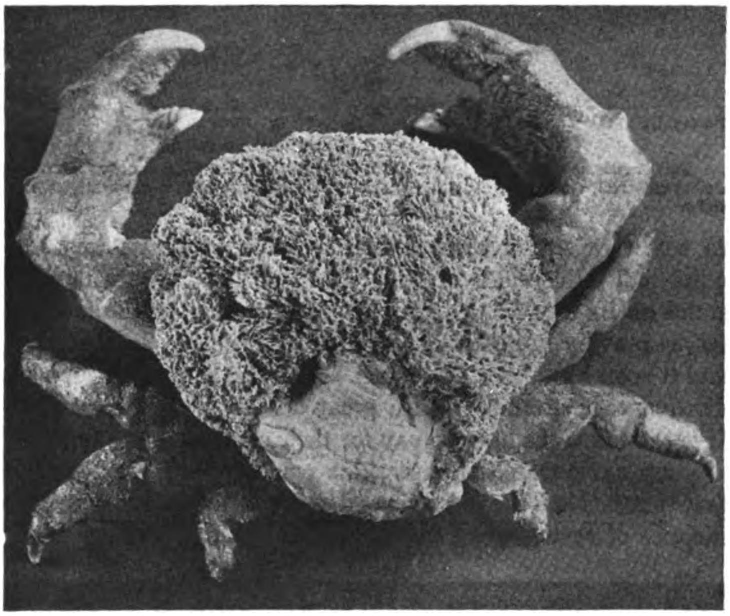


Photo: E. Step, F.L.S.

SPONGE-COVERED CRAB (*Dromia vulgaris*).

This small crab, not uncommon on British coasts, is often covered and masked by a growth of sponge. The last two pairs of walking legs are small and turned backwards and upwards. About an inch is a common length for the entire carapace.

The crab is like a knight shut up in armour which has become too small for him, and the only relief is to get a new suit. The crab's body has to be withdrawn from the protective encasement; the muscles have to be drawn through the narrow joints, which would be impossible did they not first lose much of their watery content and become a fraction of their ordinary size. In the moulting process the covering of the eye comes off and the lining of the ear. Even the hard grinding teeth inside the gizzard have to be cast out and the tendons of the muscles left behind. The shell splits along a pre-established line of weakness, and the crab comes out as soft

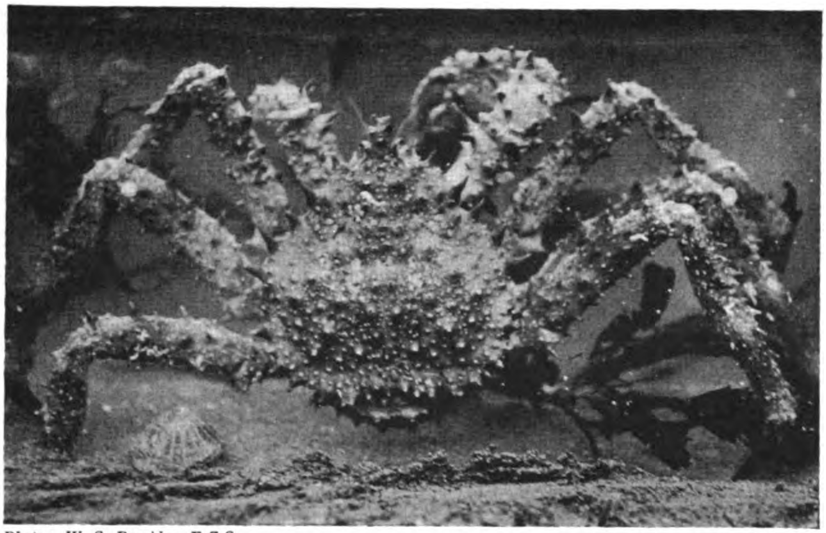


Photo: W. S. Berridge, F.Z.S.

THE STONE CRAB (*Lithodes maia*).

This handsome crab occurs in the North Sea, but the genus Lithodes to which it belongs has an almost universal representation both in shallow and deep waters. It is not nearly related to ordinary crabs.

as a wet rag. For several days it keeps very quiet—all its confidence gone. It cannot even stand on its legs. But it grows quickly on reserves previously accumulated in its soft body, and it soon has a new hard shell. Moulting is a disadvantage attendant on a great advantage. It is the tax crabs have to pay for their armour.

Many a one watching a seashore pool for the first time has had the pleasant and unforgettable surprise of seeing what looked like an empty shell of a whelk or a periwinkle suddenly unfold itself into a hermit crab and scuttle away. It is curious indeed that a member of a well-armoured class—that of the Crustaceans—should have acquired the habit of borrowing the defences of an entirely different kind of animal—a Mollusc. The present-day need for the borrowing is plain enough when we see the hermit crab's tail, for it is soft and flabby, without the usual number of limbs, and very much in need of protection. And just as the caddis-fly larvæ in the stream encase themselves in cleverly built tubes of cemented pebbles or tiny pieces of stick, and just as some crabs mask themselves with sea-weeds and sponge and such-like things, so the hermit crab makes up for what is much more than "a joint in its armour" by borrowing the substantial shell of some sea-snail, which serves at once for protection and for disguise.

The Hermit Crab.

The habit must be of very old standing, for there is hardly a part of the hermit's body that has not been changed in some way or other so that it suits the better the hermit's cell. Thus the rather ungainly tail has a peculiar banana-like twist which suits the shell's coil; of the six posterior limbs which the tail ought to bear, none are strong save the two last, which grip the central pillar of the shell so that it is not easy to pull the hermit out; on the right side

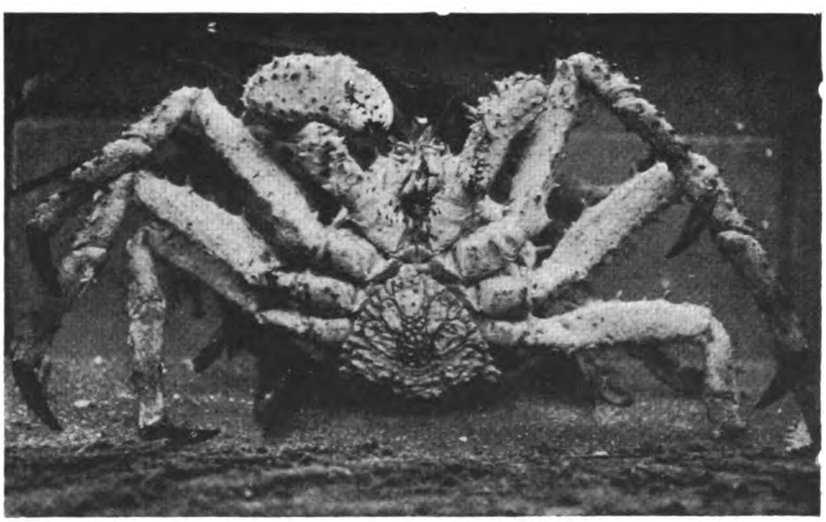


Photo: W. S. Berridge, F.Z.S.

THE STONE CRAB (*Lithodes maia*).

The tail-region or abdomen is bent up under the thorax as in an ordinary crab, but the plates covering it are complicated, as the photograph shows. Indeed the relationships of the Stone-crab are with the hermit crabs. Its ancestors probably gave up living in shells, and the tail became hard and less lopsided.

of the tail only one limb remains. One of the great forceps, which are so important in seizing food, in fighting, and in guarding the door of the retreat, is in many hermit crabs much larger than its fellow on the other side. We must not go further, but it is important to understand that the hermit's body is suited in a through-and-through way to the shell which he carries with him.

Let us turn to the animal's habits, and especially to those of the "soldier" hermit crab (*Eupagurus bernhardus*), which have been carefully studied by Mr. Gordon Jackson. One of the old naturalists, Swammerdam, who wrote a great book called "The Bible of Nature," was very positive that the hermit crab made the shell in which it lives, but this was a big mistake, for the shell is either found or stolen. Some say that the hermit crab does not hesitate to oust the rightful tenant from a coveted mollusc shell, but this has not been clearly proved. It is possible that it sometimes cleans up the remains of a whelk whose head and foot have been bitten off by a cod or some other voracious fish.

Every now and again the hermit has to leave his cell, for he has become too large for it, and he is very nervous at the time of flitting. Some one has compared him to "a bather whose clothes have been stolen," and Mr. Gordon Jackson contrasts his nervous anxiety before he finds a shell to vault into (for he is quick about it) with his "sleek impudence on safely reaching the desired covering."

The hermit crab has a large and varied appetite. There seems to be almost nothing—animal or vegetable—that is not grist to its mill. The great forceps are important in seizing the food and carrying it to the jaws and the foot-jaws, which shred it or pound it. Thence the food passes into a wonderful internal mill or gizzard, almost the same as the corresponding piece of machinery in the crab or lobster.

When we watch hermit crabs in a shore pool—an entertaining way of spending an afternoon—we cannot but form a high opinion of their capacities as alert and nimble creatures—nimble in spite of the heavy burden which they have to carry about with them. They are notoriously combative, always on the outlook to find a

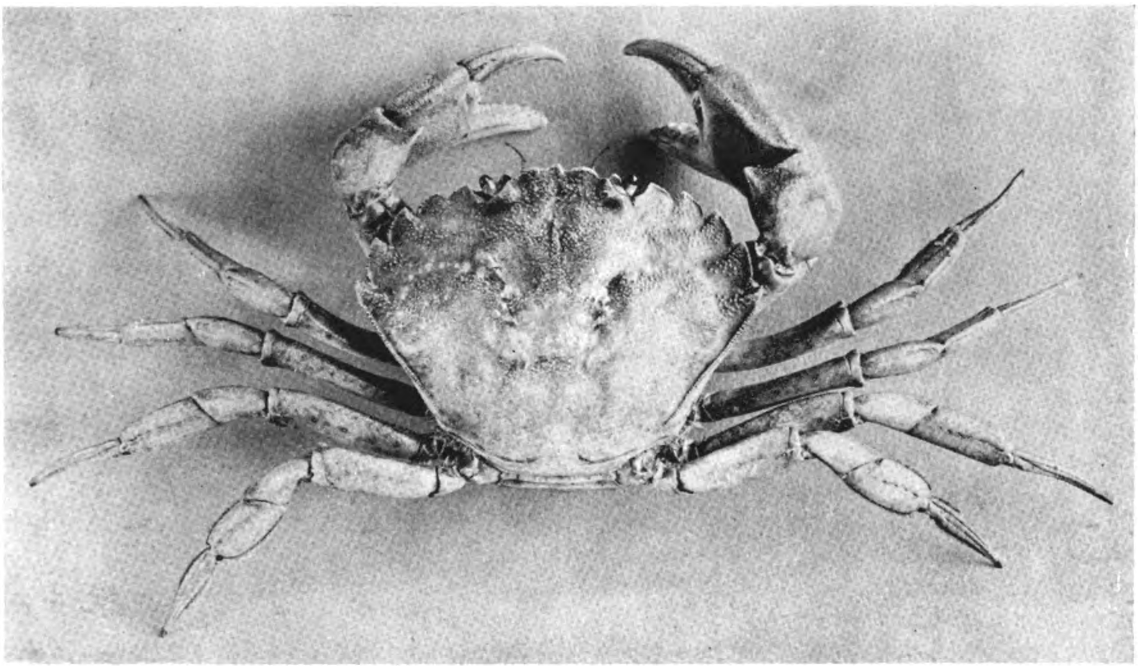


Photo: E. Step, F.L.S.

SHORE CRAB (*Carcinus mænas*).

This is one of the commonest animals of the seashore, an active, aggressive creature with a keen appetite. The young stages are free-swimming in the open sea and there is an intricate life-history before the small crabs settle down in shallow water. The photograph shows very clearly the feelers, the stalked eyes, the forceps, and the walking-legs.

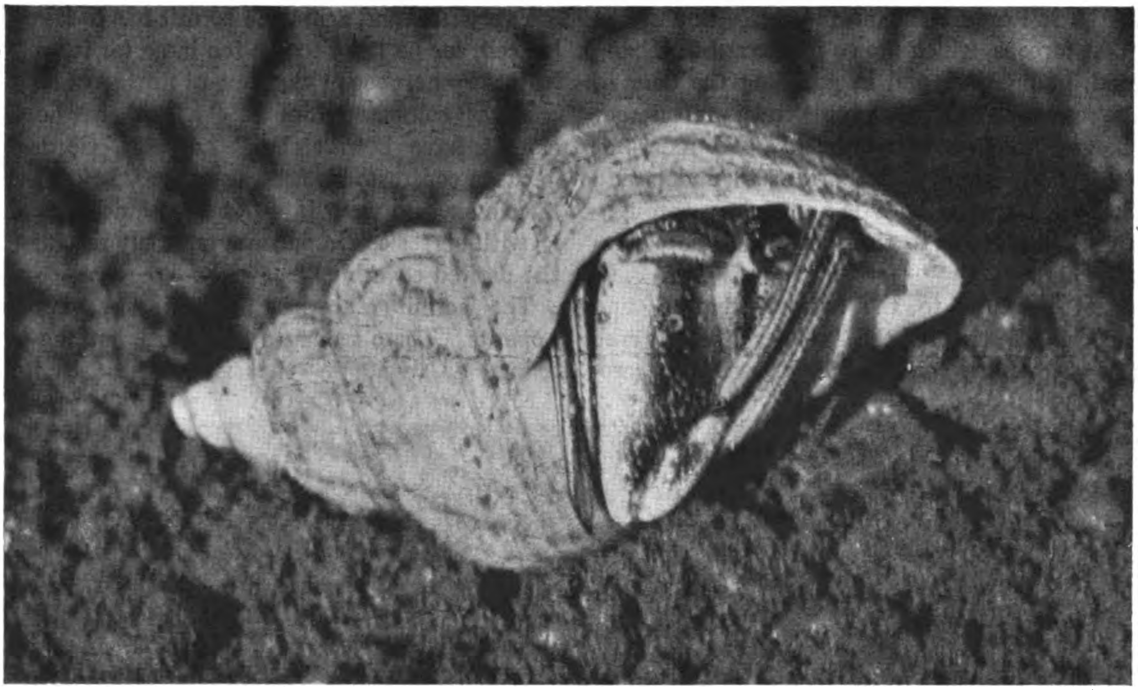


Photo: F. W. Bond.

HERMIT CRAB IN SHELL.

This large Hermit Crab, *Eupagurus bernhardus*, usually lives when full-grown in the borrowed shell of the large whelk, *Buccinum undatum*, and it is often found in external partnership with a sea-anemone, *Sagartia parasitica*. The photograph shows how the larger of the two big claws serves to shut the door of the shell.

neighbour rather too far out of his shell. The thrust is usually parried, there is instantaneous withdrawal into the recesses of the shell, and the bars of the door go home with a click. Sometimes, however, one combatant succeeds in pulling the other right out of its shell. In encounters with one another and with enemies beyond their kin, a limb is sometimes lost or badly damaged, but this matters little, since, as in many other Crustaceans, there is more or less perfect regrowth at the next " moult." By the " moult " is meant, of course, the casting-off of the hermit crab's own shell, whenever that has become too big for it. For, as we have seen, in all jointed-footed animals this happens, that whereas the animal itself grows, the shell does not, so that the animal is always becoming too big for its clothes. The inconvenience that results is remedied by moulting: the creature creeps out of its old husk, leaving it behind like a ghost of itself; and before the new suit of armour has become set the creature has a spurt of growth. In leaving its old clothes, the hermit crab first gets its head and breast disengaged, then its front limbs, and finally its tail. The whole business is one of the strangest in the animal kingdom, and is often attended with the loss of a limb or even of life itself. It is the tax that the animal has to pay for its armour—a disadvantage attendant on a great advantage. It must be remembered, also, that the soldier hermit crab which ends by being big enough to fill the great whelk or " Roaring Buckie " has, in the course of its life, experience of a considerable variety of lodgments—such as the turret shell (Turritella), the top shell (Trochus), the periwinkle and the dog-whelk.

The hermit crab enters into association with a number of other animals in addition to the Mollusc, whose empty or emptied shell it tenants. Thus there is often on the surface of the shell a colony of interesting zoophytes, called Hydractinia, and not infrequently a growth of sponge. Round about one of the hermit crabs (*Eupagurus prideauxii*), common in the Firth of Clyde, there is always a sea-anemone (*Adamsia palliata*), and the two creatures are never found apart. The hermit crab is cloaked by its partner, and probably profits also by its stinging power; the sea-anemone has the benefit of being carried

about and of feeding on the crumbs from the crab's table. It is a mutually beneficial partnership, and it is interesting to note that when the crab leaves its shell to enter a new one, it takes its partner with it. In the case of the soldier hermit crab there is often a rather quaint partnership which is beneficial on one side only. A many-legged bristle-worm, called *Nereis fucata*, shares the hermit's cell. Mr. Gordon Jackson writes: "It usually remains out of sight in the back whorls of the shell, but it appears at meal-times, thrusting its head out between the crab's foot-jaws to appropriate the very morsel on which its host is engaged."

As to the hermit crab's life-history, the mother carries thousands of eggs (12,000–15,000) fastened to the bristles of the tail appendages. There they develop into tiny free-swimming larvæ, called Zoeæ, which live in the open sea. After several moults and changes, they become what are called Glaucothöes that prowl about at the bottom of the sea during the day and rise to the surface at night. It is during this stage that they seek out houses and begin to become "hermits"—though that is anything but a good name for them, for the hermit crab is a born hustler.

Starfishes.

A fish out of water is miserable indeed, unless it be one like the mud-skipper that climbs on the rocks and mangroves on tropical shores, or like the lung-fish that lies low for half the year breathing dry air in a hole in the floor of the empty pool. But even more miserable is a starfish out of the sea. It collapses like a punctured tyre, and as the water passes out of it the life goes also. Especially in regard to such-like creatures is it true that the activity we call life is a very watery business. It is a remarkable fact that living matter contains about 80 per cent. of water. Therefore the starfish must be studied at home in the shore-pool.

It is interesting to watch a starfish hauling itself up the face of a submerged rock. It moves by means of a hydraulic system. Water is sucked in at a perforated dorsal plate, like the rose of a watering-can; it passes through a set of water-pipes to hundreds of suctorial tube-feet in a deep groove on the underside of each of the five arms.

Photo: F. W. Bond.

HERMIT CRAB MOVING OVER THE SAND

From the mouth of its borrowed shell the Hermit Crab protrudes its forceps and walking-legs and levers itself along the ground at a great rate, drawing its house with it. When it encounters something obnoxious or dangerous there is a sudden reflex action; it jerks itself back into the shell and shuts the door.

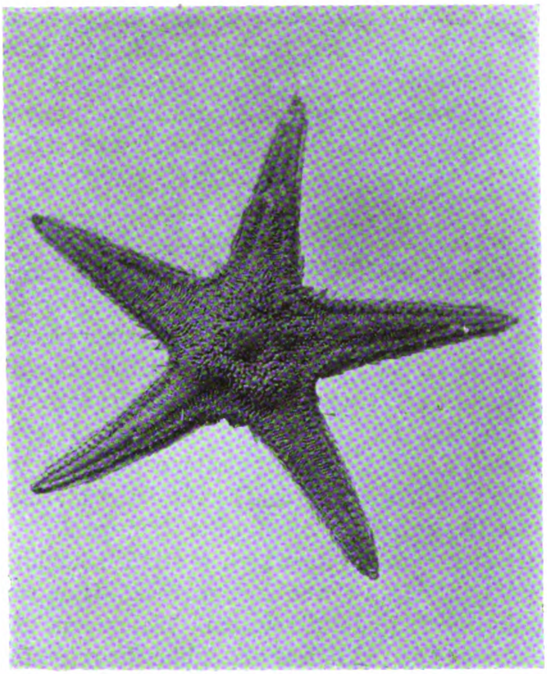


Photo: E. Step, F.L.S.

THE BUTT-THORN STARFISH (*Astropecten irregularis*).

A common species on British coasts, in which the tube-feet have no suckers. It cannot climb up rocks like the common starfish, but moves with its pointed tube-feet on hard sand. It has very muscular arms and can right itself if turned on its back.

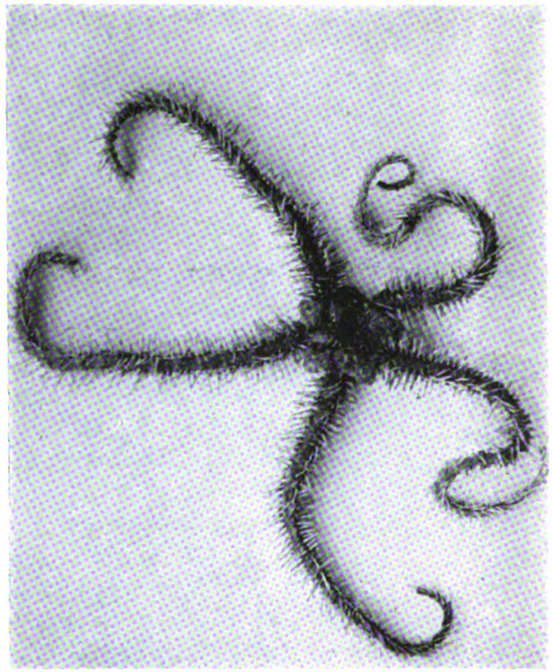


Photo: E. Step, F.L.S.

THE BRITTLE STAR (*Ophiothrix fragilis*).

One of the commonest British Brittle-stars or Ophiuroids, often swarming in shallow water. Compared with a starfish, there is much less in the central body, and much more in the muscular gymnastic arms, by means of which it pushes itself along the sand.

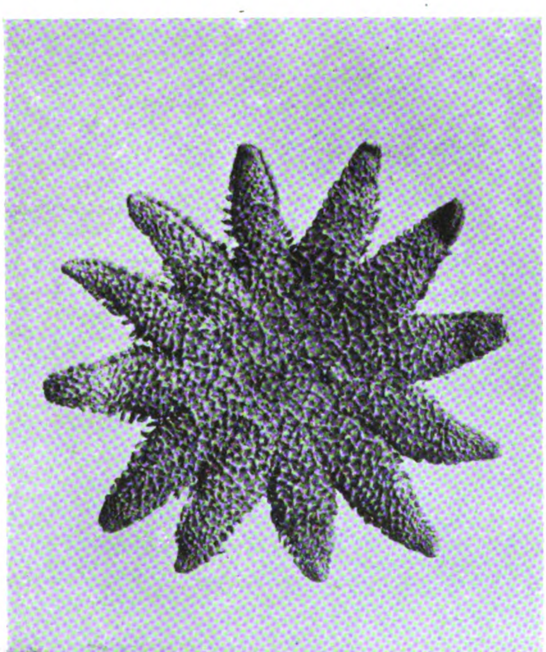


Photo: E. Step, F.L.S.

THE SUN STARFISH (*Solaster papposus*).

This common "Sun-star," found on both sides of the Atlantic has thirteen or fourteen arms of a beautiful orange to ruby-red colour. The dorsal surface, shown in the photograph, is covered with bundles or sheaves of spines; and between these there is a network of rods.

Photo: E. Step, F.L.S.

THE BIRD'S-FOOT STAR (*Palmipes membranaceus*).

A peculiar starfish, flat and thin like a pancake, lives off British coasts in deepish water. The pentagonal form is due to a shortening down and broadening out of the arms. The dorsal surface is covered with overlapping plates, with few spines.

These tube-feet become tense, like a hose-pipe when water flows into it, and they are pressed against the rock, like so many firm fingers. Then the water flows out of them into little bladder-like reservoirs (ampullæ) arranged in rows in the inside of the arm, and the result of this is to make the starfish adhere to the rock. The fact is that a partial vacuum is formed between the tip of the tube-foot and the surface of the rock, a little like the partial vacuum which street boys make on the pavement with a leather sucker and a string. The starfish then contracts the muscles in the wall of the tube-feet, so that they become shorter. This draws the creature up to the place of its attachment, just as the shortening of a hawser draws the ship close to the side of the pier. The next step is to inject water with some force from the contractile reservoirs into the tube-feet, obliterating the partial vacuum and setting the tube-feet free. The starfish would then fall down again, were it not that meanwhile another half hundred tube-feet on another part of the arm, or on another arm altogether, have been fixed higher up. So the starfish climbs the rock—as quickly as a snail!

It often happens on the seashore that the waves dislodge a stone, which then pins down some unfortunate animal. When a heavy stone imprisons a starfish's arm, or when a sea-slug gets on to an arm and begins to secrete sulphuric acid from its mouth, why, then there is *autotomy*. This curious word, meaning self-mutilation, is the technical term for surrendering a part to save the whole. And it works very well, for the starfish that has escaped from deadly peril can regrow another arm at its leisure. Along the ventral groove of each arm there is a strand of nerve-cells, the five strands being united in a pentagon around the mouth: and then there are scattered nerve-cells here and there. But the starfish has no brain, not even a single nerve-centre or ganglion, so that when it gives off a limb to save its life, it does not know what it is doing, as we count knowledge. What happens is due to a very forceful contraction of muscles at the base of the arm, so forceful that the arm breaks off; but this is an action comparable to ours when we draw away our finger from something very hot, without willing, almost without knowing; it is a reflex action. Animals can learn without understanding, just as many people do in mastering some dexterity. They get the "hang of it," but not the idea of it. The fact remains that in the course of time the starfish has learned in its constitution, if not in its mind, that it is better that one member should perish than that the life should be lost.

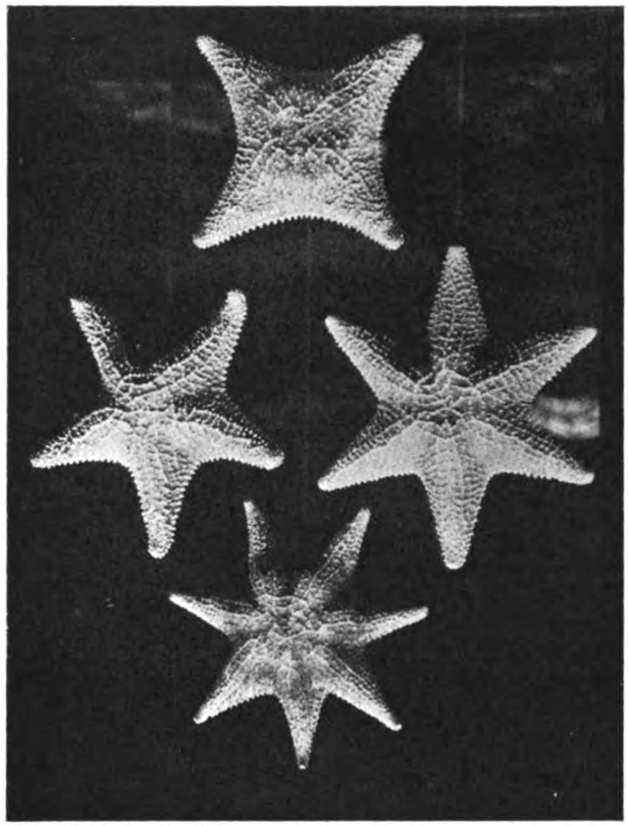


Photo: W. S. Berridge, F.Z.S.

VARIATIONS OF THE WEST INDIAN CUSHION STARFISH (*Pentaceros reticulatus*).

Among starfishes there are frequent variations or new departures. Thus the photograph shows individuals of this Cushion-starfish that have four, six and seven arms or rays, the normal number being five. Some of these variations are seen from the time when the animal puts on the adult form; most occur in connection with the regrowth of an arm that has been lost.

Unlike most soft-mouthed or jawless animals, the starfish is a carnivore, and it is very fond of mussels and small oysters. It gets above the mussel and fastens an arm to each of the two valves of the shell; it hunches its body up and shortens its tube-feet so that the valves are steadily pulled asunder. It goes on doing this for

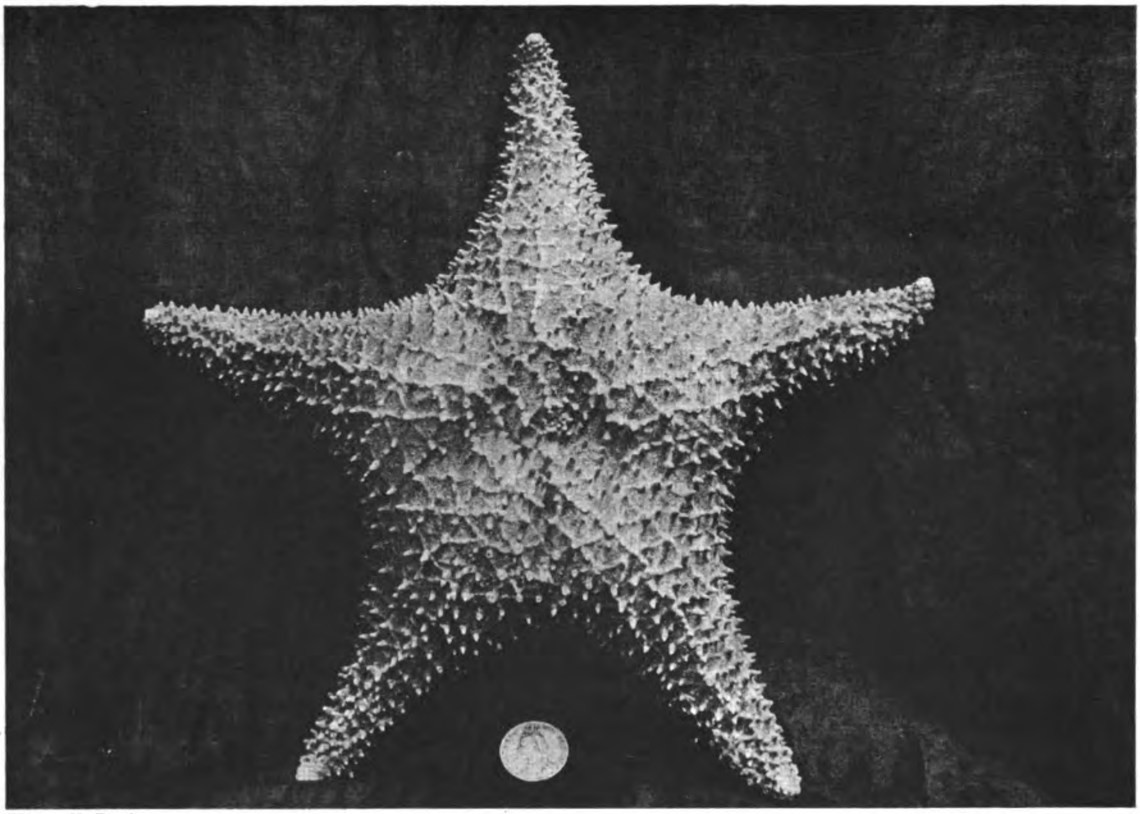


Photo: H. Bastin.

A GIANT STARFISH (Pentaceros).

A large Indian Ocean starfish, whose size may be inferred from the florin photographed beneath. The dorsal surface is very decorative, with a network pattern. The arms are of moderate length. There are no near relatives in British waters.

some time using successive relays of tube-feet, till the mussel becomes fatigued (for keeping the valves firmly closed is an effort) and gapes. Whereupon the starfish insinuates between the gaping valves its capacious protrusible stomach, rich in digestive juice. In dealing with oysters it favours small ones, over which it can outfold its smothering stomach. Some starfishes will even eat the bait off the fisherman's lines. It is said that the fishermen in revenge sometimes tear the starfish they catch into five parts and throw these into the sea. But this is not a wise thing to do, for each arm may, in favourable circumstances, grow a new starfish. We often get what are called "comet" forms of starfish, where one arm is just beginning to regrow the lost four.

A starfish, as large in appetite as it is small in wits, has some resoluteness. For it will tackle a small sea-urchin in the shore-pool. It lays an arm on the hedgehog-like surface, and it gets its soft tube-feet nipped by hundreds of little stalked snapping-spines (pedicellariæ) which project among the big spines like so many minute three-bladed scissors. But when these snappers have gripped the soft tube-feet they cannot quickly let go, and when the starfish moves away its arms they are wrenched off with it. The starfish does the same with another arm, and with another, without haste or rest, till it has disarmed the sea-urchin. Here we see a brainless creature following a line which is not the line of least resistance, and working steadily towards a distant goal. This is the threshold of *Endeavour*.

Sea-urchins.

As another type of coast-animals we take the sea-urchins, admitting as before that many of them have long since left the shallow water and explored the great depths. Strange prickly balls, they got their name from their resemblance to hedgehogs in the old days when it was believed that the creatures of the sea were counterparts of those on land. But the hedgehog and the sea-urchin—Mammal and Echinoderm—are as far apart as two animals could well be. They agree only in their prickliness.

At the south pole of this living globe there is a small mouth through which five strong teeth project. Around this there are ten large tube-feet used in tasting the food. Further out there is a broad, soft circle bearing many spines, and where this joins the hard shell there are ten branched gills, only visible when the animal is in good condition and in the water. At the north pole of the globe there is a complicated apical disc, best studied by rubbing the spines off a dead sea-urchin. The food-canal ends in the middle; around this are five plates, through apertures in which the germ-cells are shed into the sea; between these are five smaller plates through which a sensitive tentacle-like tube-foot is protruded. One of the five inner plates is larger than the other four, and is covered like the rose of a watering-can with minute pores, through which water is ceaselessly wafted in to work the hydraulic system of water-tubes used in locomotion and also in respiration.

Now, to cut a long story short, there extend from the "north pole" to the "south pole" five broad meridians bearing spines and five narrow meridians bearing not only spines but locomotor tube-feet. As the sea-urchin grows, new plates are added round the circumference of the apical disc; but each plate can also be added to by the adjacent living tissue.

There are three ways in which a sea-urchin moves. It uses its spines like stilts which can be swayed in any direction. Like a starfish, it uses its tube-feet for climbing up the rock, attaching them, shortening them, releasing them after fixing others. But on a level stretch of firm mud, the sea-urchin protrudes its five teeth and hobbles along on their tips, tumbling a little from side to side. The curious mechanism should be studied by breaking open a dead sea-urchin. It is called Aristotle's lantern, for he saw it more than two thousand years ago. Besides levering the animal along, it is a chewing apparatus, crunching up seaweed and small animals, and it also helps in breathing. In the golden-yellow heart-shaped sea-urchin which burrows in the sand, the spines are the only locomotor structures: the tube-

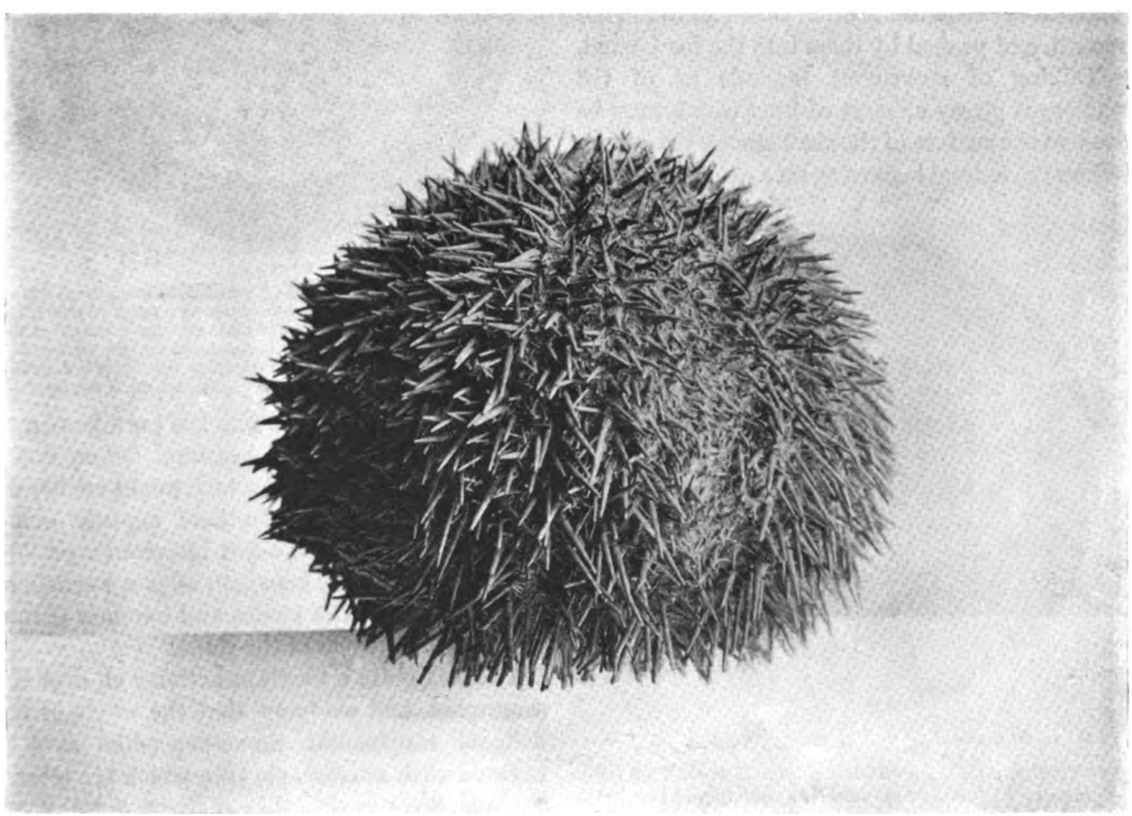


Photo: E. Step, F.L.S.

THE COMMON SEA-URCHIN (*Echinus esculentus*).

The globular shell or test is covered with spines which work on ball and socket joints and help in locomotion. But the chief locomotor structures are the soft tube-feet which can be protruded far beyond the spines, and can be firmly attached to the surfaces of rocks up which the sea-urchin can creep.

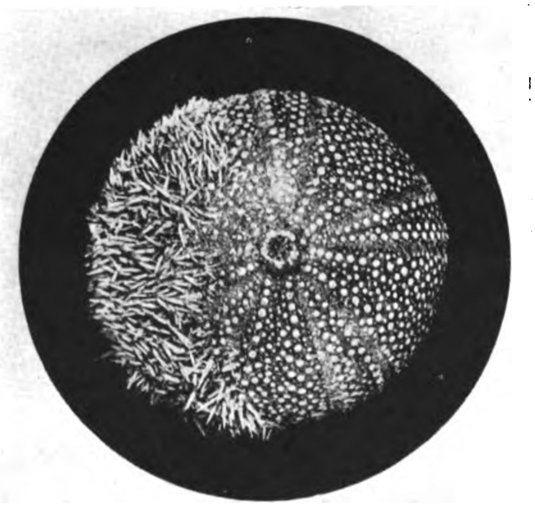


Photo: G. H. Hewison.

SEA-URCHIN WITH SPINES REMOVED.

From part of this sea-urchin the spines have been rubbed off to show the little balls on which the sockets of the spines work. In the centre, which is the pole opposite to that at which the mouth lies, there is an "apical disc" of ten plates surrounding the end of the food-canal. One of these ten plates, called "madreporic," serves for the entrance of the water that works the hydraulic tube-foot system used in locomotion.

feet are used for collecting microscopic organisms, which are transferred to other tube-feet round the mouth, and pushed by them into the food-canal.

Talking of movement reminds us of the numerous glassy spheres of lime which may be seen on the surface of the shell among the spines. When the animal is moving on a slope the heavy heads of these transformed spines droop towards the lower side, and they thus serve to give the animal information in regard to its position. In other words, they are balancing organs, with a function somewhat like that of certain "gravity sacs" in connection with our ears which enable us quite automatically to keep our erect posture in running.

When we watch a sea-urchin in a basin of water, we see a great activity all over its surface. The spines sway on their ball-and-socket joints; the translucent tube-feet search about for some support; and among the spines there are minute snapping-blades or pedicellariæ, mounted on stalks. Some of these snapping blades give poisonous bites, and one bite has been known to make a frog's heart stop beating. Others catch and kill minute creatures which might anchor on the sea-urchin's shell; others capture small animals which the tube-feet afterwards pass to the mouth: and others again seize a particle of grit with two of the blades and hammer it into powder with strokes of the third.

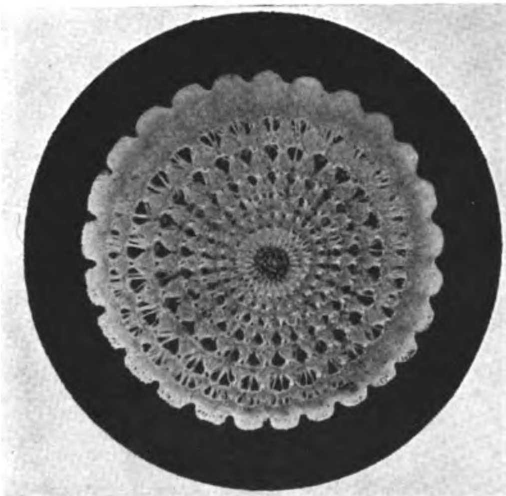


Photo: G. H. Hewison.

CROSS-SECTION OF SPINE OF SEA-URCHIN (Magnified 26 times).

The interior of the spine of a sea-urchin shows a zoned structure, like the trunk of a tree cut across. The circle near the centre shows the size of a young spine; the rings are the additions that are made season after season. The dark spaces are empty, so that there is considerable economy of material—strength without too much weight.

There is quite a bustle of activity all over the sea-urchin, and we know that the whole of the delicate transparent tissue-paper-like skin is covered with microscopic cilia which are always wafting, just like those in our air-passages. Each snapping-blade can act on its own, and each spine likewise, for the sea-urchin has no brain in

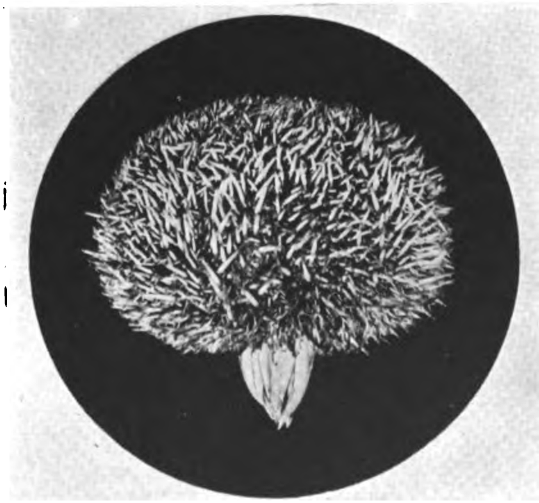


Photo: G. H. Hewison.

SEA-URCHIN, WITH ARISTOTLE'S LANTERN DRAWN OUT.

At the mouth-pole of the sea-urchin there is an elaborate apparatus which serves for chewing, and also, on a flat surface, for hobbling along. There are five teeth in five sockets. The teeth project from the mouth for a short distance; the drawing out of the lantern shown in the photograph is quite artificial.

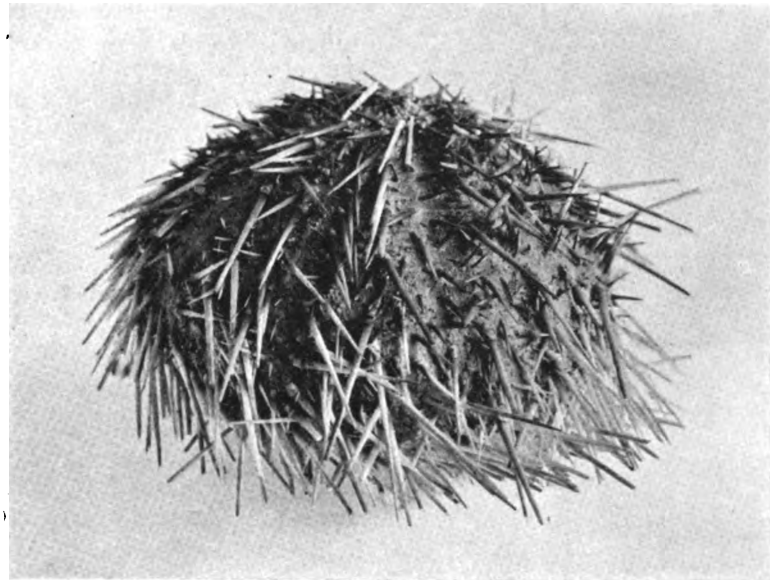


Photo: E. Step, F.L.S.

SHARP-SPINED SEA URCHIN (*Echinus acutus*).

This species of sea-urchin is closely related to the common *Echinus esculentus*, but seems to be quite distinct. One of the differences is the presence of longer and sharper spines. It is not uncommon in the North Sea.

the ordinary acceptation of the term. The movements of the snapping blades and spines are "reflex actions," taking place automatically, like our coughing when a crumb threatens "to go down the wrong way." There are so many of these automatic reflexes in a sea-urchin that the animal has been called "a republic of reflexes," and the wonder is that the multitudinous movements of spines and snappers and tube-feet work out so harmoniously.

There is a loose network of nerve-cells and fibres beneath the skin, by which news can be passed from one part of the animal to the other. There is also a nerve-ring round the mouth and a branch running up each of the five areas through which the suctorial tube-feet are protruded, but though this helps to make the different sections of the body work in unison, it cannot be called a controlling centre. "In a dog the animal moves its legs; in a sea-urchin the legs move the animal."

Sometimes a gull lifts a sea-urchin from among the low-tide seaweeds and lets it fall from a height so that the shell is broken. Sometimes a starfish disarms a small sea-urchin and smothers it by protruding its elastic stomach. There are other dangers, but is there any animal less vulnerable? The fact is that the sea-urchin's struggle for existence is mostly in its early youth, which is spent as a free-swimming pinhead larva in the open sea, away from the rough-and-tumble life of the shore. There are immense numbers of these delicate, transparent larvæ—each like an inverted easel with many legs—and there is great mortality among them, for they form part of the edible dust of the sea.

Sponges.

As examples of coast animals, characteristic of comparatively shallow water, we take Sponges, although there are many of them that live on the floor of the sea at great depths. At first sight they do not look like animals at all, and we cannot wonder that early naturalists

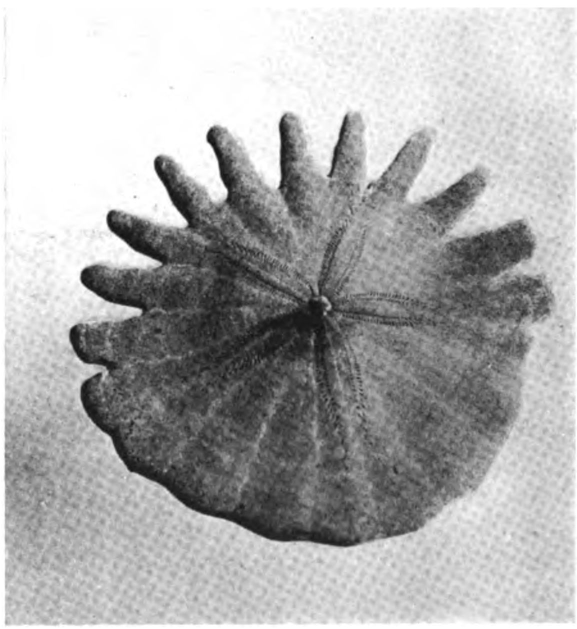


Photo: E. Step, F.L.S.

WHEEL URCHIN (Rotula) FROM AFRICAN COASTS.

In the family Scutellidæ there are numerous peculiar sea-urchins marked by a greatly flattened body, the indentation of the outline, and the branching of the tube-foot (or ambulacral) grooves on the under surface. In this case the margin is produced into finger-like processes. The photograph shows the dorsal surface with five tube-foot (or ambulacral) areas, radiating around the apical disc.

Photo: W. S. Berridge, F.Z.S.

FLORIDA CUP SPONGE (*Euspongia officinalis*, variety *punctata*).

One of the many varieties of the Bath Sponge, here taking the form of a cup. The finest Bath Sponges are from the Adriatic; coarser varieties are fished off Dalmatian and North African coasts, from the Greek Archipelago, from the West Indies, and from Australia.

ranked them among the plants. They are fixed, they have no readily visible way of feeding, they bud and branch. Certainly they are what we should call vegetative animals. Dr. Nehemiah Grew regarded them in 1686 as corresponding to "one half of a plant"—the pithy part. A century later there were many who held that sponges were but the houses of worms, a misinterpretation probably due to the fact that worms are sometimes found burrowing in the interior. Gerarde, in his famous Herbal, figures sponges along with seaweeds and mushrooms, and wriggles away from the problem by saying: "There is found growing upon rockes near unto the sea a certaine matter wrought together of the foame or froth of the sea which we call Spunges . . . whereof to speak at any length would little benefit the reader (a warning to us), seeing the use thereof is so well known." But much more interesting than these errors is the extraordinary fact that Aristotle (384–322 B.C.) had reached the conclusion, characteristic of his lucidity, that sponges were animals, though with some likeness to plants.

An English naturalist, Ellis, had pointed out in 1765 that sponges showed their genuine vitality by "sucking and throwing out water"; but the first fundamental observation on sponges is to the credit of a Scottish naturalist, Robert Grant, who had the satisfaction of seeing small particles in the sea-water disappearing into the sponge through minute pores and reappearing at the large exhalant openings. He tells us how, about 1835, he put a little branch of a living sponge in a watch-glass under a microscope, and reflected through the sea-water the light of a candle. "I beheld, for the first time, the splendid spectacle of this living fountain vomiting forth from a circular cavity an impetuous torrent of liquid matter, and hurling along, in rapid succession, opaque masses, which it strewed everywhere around." It is plain that Dr. Robert Grant had the proper spirit, and his vivid drawing of the inflowing and outflowing currents is often reproduced in books of to-day. He guessed rightly that the currents were kept agoing by ciliary action, but he was not able to find the cilia.

If a student of zoology were asked nowadays why sponges are not to be regarded as plants, he would answer that they feed on in-wafted *solid particles*; that the cells of their body are not in the least like those of plants, e.g., in not

having cellulose walls; and that the free-swimming juvenile stages of sponges are in a general way like those of many other marine animals.

A living body is often compared to a city, which seems to us a better comparison than likening it to an engine. The quarters of the city, where certain things happen, the marketing and administrative quarters, for instance, are organs; streets of similar houses or shops, like the old Paternoster Row, are tissues; the houses or shops are the cells; and the inhabitants are the vital units of different kinds that co-operate in a cell-firm. If we compare an ordinary animal body to a city, we must compare a sponge to a city like Venice, where everything depends on the canal system. The canals bring in food and freshness; they sweep away débris and waste; they bring the different parts of the body (or city) into communication with one another.

When we ask Robert Grant's question: What keeps up this two-fold set of currents, inhalant and exhalant, we can now give the answer—the ceaseless lashing of energetic internal cells situated on the canal system and whipping the water past. Sometimes the outgush from an exhalant opening is so forcible that it makes a distinct disturbance on the surface of the water a foot overhead. It is possible to fix a glass tube neatly into one of these openings, which often look like the craters of volcanoes, and then one can see the height of the column of water that the sponge's vigorous activity can support.

This shows once more how careful we should be not to judge by first impressions. It seems so obvious that a sponge is a sluggish creature, and yet it is the very reverse. Day and night it is lashing through its body a prodigious quantity of water, and this means a great expenditure of energy. From the water it captures the microscopic organisms and particles on which it feeds, and from the water it captures the oxygen which keeps the fire of its life burning. It is not what you would call a fussy animal, but it does a great deal of work.

Sponges occupy an interesting position in the animal kingdom. They were the first animals to be successful in having a body, and, though they have no organs in the strict sense, they show the beginnings of tissue, especially muscular tissue. When an inquisitive worm pokes its head into an exhalant opening of a sponge, it sometimes happens that the opening is quickly narrowed,

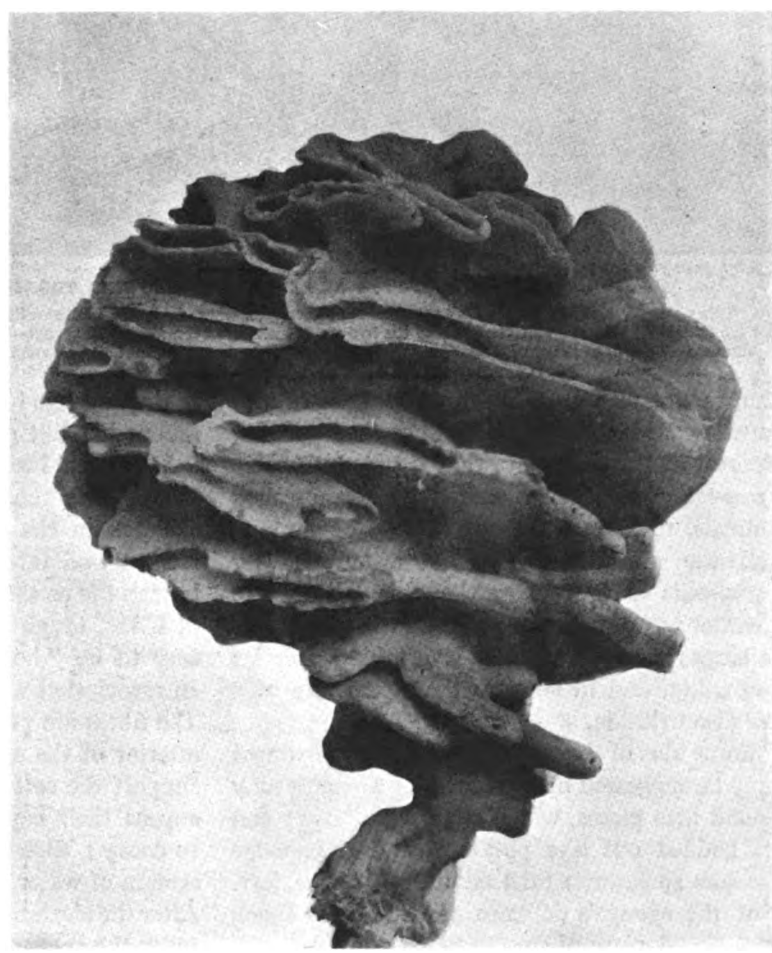


Photo: W. S. Berridge, F.Z.S.

SPONGE (*Aphrocallistes vastus*), FROM SAGAMI BAY, JAPAN.

A deep-sea flinty sponge in which a fundamental cup form has been much modified by the outgrowth of lateral shelves. The six-rayed spicules are bound together from the first into a firm framework.

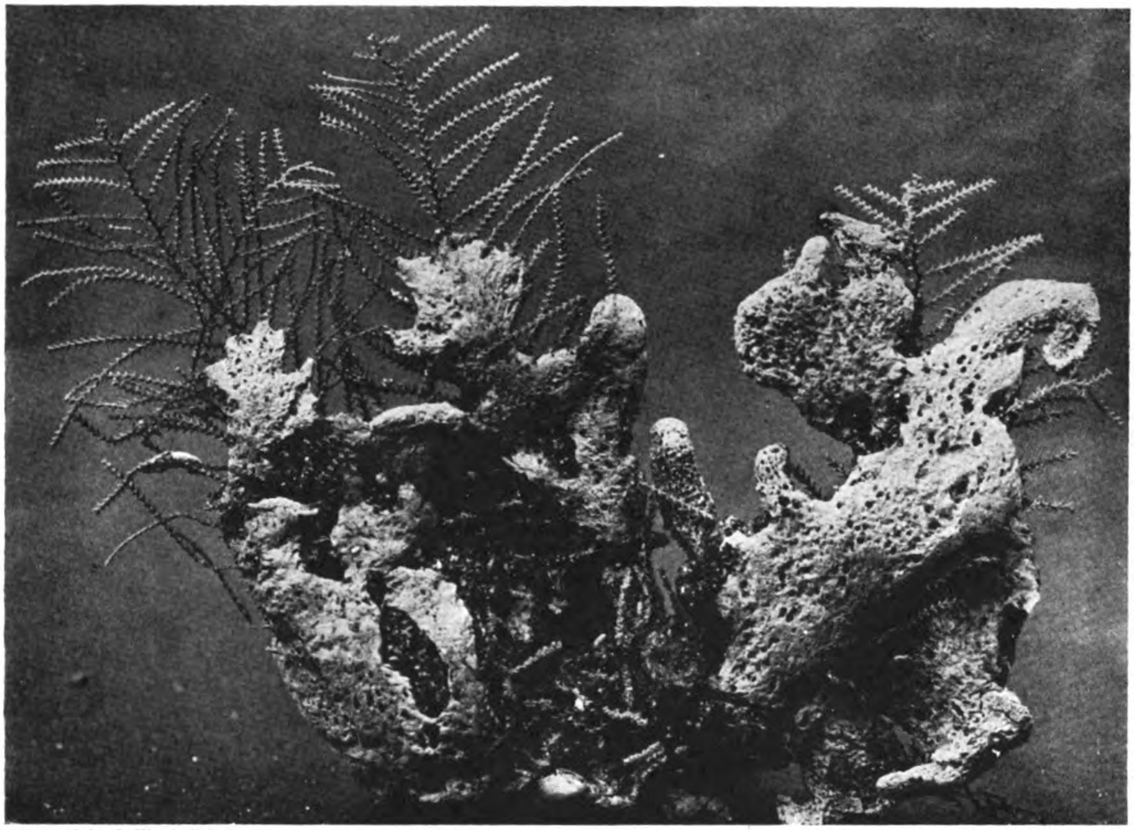


Photo: John J. Ward, F.E.S.

SPONGE AND ZOOPHYTE GROWING TOGETHER.

This photograph shows a "Sea-fir" or Sertularian Zoophyte, whose branches, with saw-like edges, bear numerous cups or hydrothecæ for the individual polyps. But the bases of the hydroid colonies are overgrown with sponge—an epizoic association without much, if any, significance. Instead of being of advantage, the growth of sponge is apt to smother the zoophyte.

though not closed. This means that a ring of muscle-cells has contracted. There is a peculiar interest in this—namely, that *the sponge has no nerve-cells.* In sponges, the lowest many-celled animals, division of labour is only beginning; and the muscle-cells are not stimulated by nerve-cells as is usually the case. They are themselves directly provoked to action by messages from outside. Everything has its beginning, and in sponges the contractile cells are also irritable.

Some idea of the relative simplicity of sponges may be suggested by the fact that a sponge may be cut into pieces, which all survive. They can be bedded out like potatoes, and the sponge farmers sometimes take advantage of the fact. But the sponge's defiance of death goes much further. A piece of sponge may be minced, and the mince forced through a straining cloth; a small quantity of this mush will in appropriate conditions pull itself together and develop into a tiny sponge! This means that division of labour has not gone far in the sponge body.

We often hear of the skeleton in the cupboard, but there is more reality about the skeleton in the bathroom. No other skeleton has entered into such intimate relations with human life as the bath sponge. It is a labyrinth of fibres, tough and yet soft, said in a general way to be "horny," but perhaps nearer silk, In association with the spongin there is iodine. The fibres are products of the living cells in the interior of the sponge, and their function is to support the soft tissues. The sponge fishermen expose their captures till the soft flesh begins to decay; then they are beaten or trodden in a stream of water till all the cells are washed out. After the cleaning, which must be done very carefully, the sponges are dried in the sun. When a sponge in domestic use becomes unpleasant and slimy, that is due to gelatinous masses of bacteria which are multiplying in the recesses

of the labyrinth. The remedy is to use hot water and a disinfectant, and then dry thoroughly.

When we say "sponge" we always think of the familiar skeleton of the Bath Sponge, Euspongia. But there are, of course, many hundreds of different kinds. Some are on the sea-shore, like the Purse Sponge (Grantia), whose name recalls Robert Grant, and the Crumb of Bread Sponge, covered with crater-like exhalant apertures, that forms familiar encrustations on the rocks. Some are anchored farther out, like the Mermaid's Gloves, often tossed up on the beach after storms, and the large Cup-Sponges, and the spherical Sea-Apples. Others, again, are fastened on the floor of the true Deep Sea, like the Glass-Rope Sponge, which is raised out of the ooze on a long stalk of flinty threads, tied together in a firm bunch by a growth of small sea-anemones. Then there is Venus's Flower Basket (Euplectella), which has a flinty skeleton like a fairy campanile. It is an extraordinarily beautiful piece of architecture, but during the life of the sponge it is wrapped up in a garment of cells. The skeleton of a sponge may consist of flint, or of lime, or of spongin (as in the Bath Sponge), or of both spongin and flint. Many British sponges have a large skeleton of spongin, but they cannot be used instead of the Bath Sponge, the reason being that their spongin is associated with myriads of flinty spicules. The effect on the human skin would be disastrous! The spicules often form an internal support, but they also make their possessors practically inedible. There are animals that burrow in sponges, but hardly any animal tries to eat them. In many cases there is also a strong odour, sometimes like iodoform, which is probably repellent.

Like most other animals, sponges may become linked to other lives. Thus there is a bright orange-coloured sponge (*Suberites domuncula*) that grows right over the whelk shell that a hermit-crab has borrowed. It serves as a very effective mask. Several different kinds of crab, such as the common Sand Crab, are in the habit of sticking pieces of sponge on to their carapace and legs, thus disguising their predatory character under a camouflage of innocence. Within some sponges there occur thousands of microscopic Algæ, plants and animals living together in a mutually beneficial partnership or symbiosis. In the family of freshwater sponges (Spongillidæ), which have migrated from the original home in the sea, to which all the other families are restricted, the minute Algoid partners are sometimes so numerous that the whole animal is coloured green. Another curious linkage is illustrated by one of the cuttle-fishes that deposits its eggs in pockets in the substance of a flinty sponge. Interesting also is the habit of the little boring sponge, Cliona, which manages to perforate oyster-shells, and thus helps to reduce a massive bivalve to the level of sand. Some of the boring sponges remain dwarfed like Cliona when they assume the burrowing mode of life, but grow almost unrecognisably large when they live in freedom, which things are like

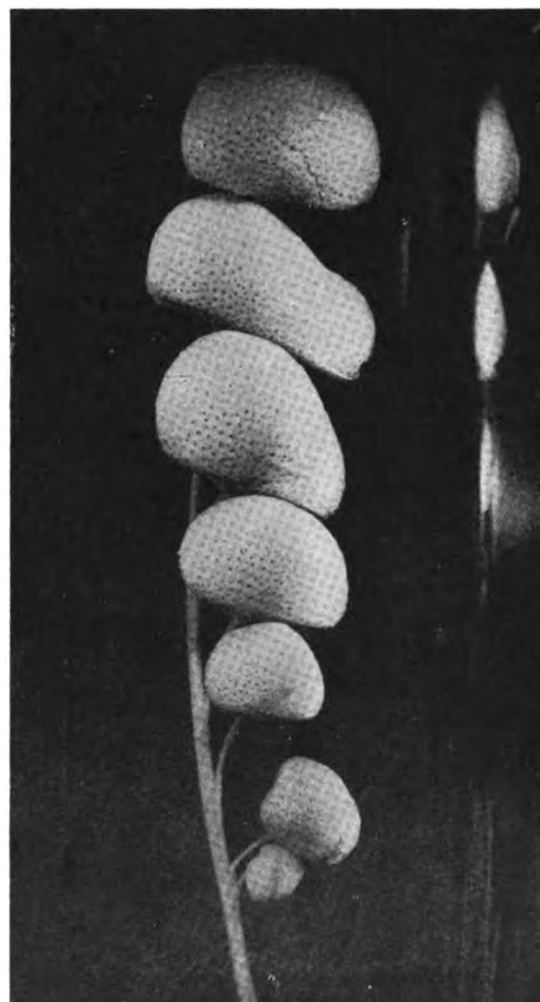


Photo: W. S. Berridge, F.Z.S.

CELEBES SPONGE (*Esperiopsis challengeri*).

A very striking deep-sea Flinty Sponge, which has evolved in the stillness of the abysses an unusual mode of growth and a new secondary symmetry. Its near relatives in shallow water show variable and irregular shapes.

Photo: W. S. Berridge, F.Z.S.

LEVANT LAPPET-SPONGE (*Euspongia officinalis*, variety *lamella*).

One of the many varieties of the Bath Sponge. The skeleton, familiar to all, consists of a coherent felt work of solid fibres. These are composed of an organic substance, called spongin, which is characteristic of the class of sponges, but is usually accompanied by spicules, which are absent in the Bath Sponge.

a parable. Our concluding remark must be that sponges represent a cul-de-sac in evolution. They are very successful; there are hundreds of different kinds; they often show great complexity at a low level; many of them are wonderfully beautiful, but they do not lead on to anything else. They are off the main line, and in a blind alley. One reason may be that when the very young stages settle down after a short time of free-swimming, they fix themselves by the mouth—certainly not a progressive thing to do. Another reason may be that they have no nerve-cells, for without these we cannot expect an animal to go far.

Sea-horses.

In the early days of Natural History the discoverer of a strange animal in the sea had to face the difficulty that he could not get his friends to believe his story. One way of winning conviction was to produce the specimen, but that was not always easy. Another method was to submit a drawing. Another method was to say: "After all, what I saw is not so incredible; it was simply the sea's counterpart of what you are familiar with on land." Thus grew up the notion that there were marine "doubles" of many of the terrestrial types. This is seen in many of the names given to sea animals in many different languages—sea-anemones, sea-butterflies, sea-cucumbers, sea-devils, sea-eagles, sea-fans, sea-gulls, sea-horses—and so on down to sea-urchins and further.

The sea-horse (Hippocampus) is one of those animals that provoke a smile. It borders on the

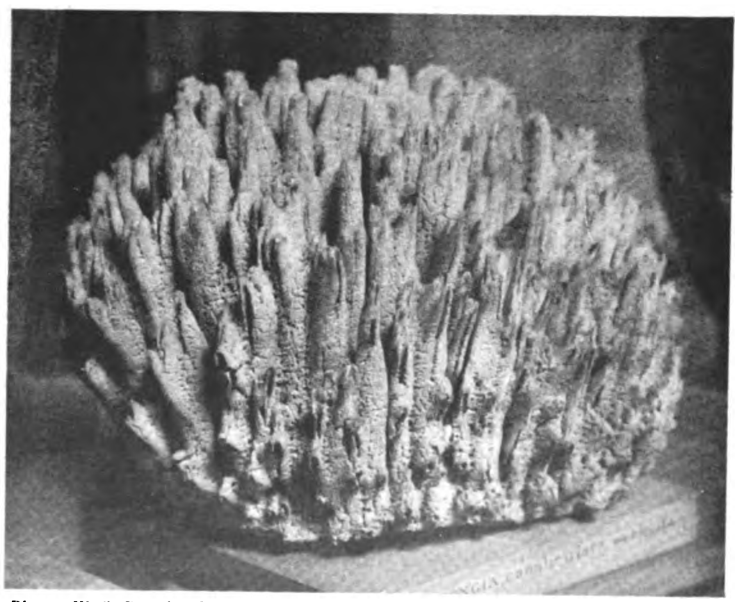


Photo: W. S. Berridge, F.Z.S.

BAHAMAS SPONGE (*Euspongia canaliculata*, variety *elegans*).

Another variety of the Bath Sponge, marked by its mode of growth and fine texture. It consists of a large number of tubular branches. The large openings or oscula serve for water passing out. The water enters by very numerous pin-prick openings in the skin.

ridiculous—with the head of a horse and the prehensile tail of a monkey. Dr. Theodore Gill compared it to a knight on the chess-board mounted on the dainty coiled shell of the little cuttlefish called Spirula; and the second half of the technical name Hippocampus is Greek for a curled-up caterpillar or worm.

Ordinary fishes move their body from side to side, jerking out masses of water to right and left; but the sea-horses have a very stiff bucklered body and their coiled tail moves up and down like a chamæleon's. Another element in the quaintness is the independent movement of the two eyes, a peculiarity which is also exhibited by the lizard we have just mentioned. That in itself is a curious point.

Sea-horses are widely represented by various kinds in most warm and temperate seas, and they are familiar, though fastidious, inmates of aquaria. It is a great pleasure to watch their quaint movements, which are never hurried. There seems to be an adjustment of the gas in the swim-bladder to the specific gravity of the sea-water so that the sea-horse requires little or no effort to keep afloat. A favourite resting pose is bolt upright with the tail coiled round a stalk of seaweed.

Sometimes the creature sinks slowly downwards as if on a hinge. Then it lets go and moves in the water by the extremely rapid undulatory movements of the single dorsal fin, helped by the quick strokes of the delicate paired pectorals. It always tends to fall forwards in the water, but quickly recovers itself, and is vertical once more. The movements are too slow for hunting purposes, and we believe that the sea-horse uses its little mouth in a somewhat pipette-like fashion to suck up young crustaceans and other small fry from the fronds of the seaweed or from the substratum. Excepting those kinds that live among floating seaweed in the open ocean, the sea-horses are at home in well-illumined, seaweed-bearing, relatively shallow in-shore waters.

Photo: W. S. Berridge, F.Z.S.

SILICEOUS SPONGE (*Rhabdocalyptus victor*).
A beautiful Flinty Sponge with six-rayed and eight-rayed siliceous spicules. It is distantly related to Venus's Flower Basket (Euplectella).

A careful observer has noticed that sea-horses make at intervals "a sharp little snapping noise," which seems to be produced by very rapid quivering movements associated with opening and shutting the lower jaw. They must not be thought of as chattering, for the sound in our British species is slender and monotonous;

but it is interesting to know that one sea-horse answers another, that the sounds are made by both sexes, and that they are more frequent and intense at the breeding season. It is comical, somehow, to think of the delicate "neighing" of the sea-horse. But we must turn to something much more remarkable than conversation.

On the under-side of the front of the male's tail there is a capacious pocket. It is formed by the fusion of two folds of skin and has an anterior opening. Into this opening the female presses a few eggs at a time and it is apparently in the course of the transfer that they are fertilised by the male. After a short time the female comes back again to lay more eggs in her partner's pocket! What is more, several females may take advantage of one male. All this is very quaint.

The eggs develop in the water-tight pocket and they seem to be fixed and partly nourished by the spongy internal lining, which becomes very rich in blood-vessels. As is usual in fish eggs, there is a considerable amount of yolk which is gradually used up as development goes on.

After a while the minute sea-horses have taken shape and become restless within their cradle. The father-fish presses his monkeyish tail up against his pocket, and a few young ones are expelled at the anterior opening which has begun to gape. Or it may be that he presses the pocket against a winkle-shell and thus secures the expulsion of the fry. This is a very strange occurrence for it looks as if the male fish was giving birth to young ones. According to one observer, each effort is followed by a few minutes' rest, three to six youngsters are set free at a time and the whole business may last for about six hours.

The newly liberated young ones swim away and are lost among the seaweed. In the common Mediterranean sea-horse they are towards half an inch long, and are like miniatures of the parent except that the big scales have not developed and the snout is relatively shorter. It is not the case that they go back into their father's pocket when danger threatens. Some people expect too much, and as the old naturalist, Topsell, wrote in his "Apologia" (1607): "God needeth not the lies of men."

Many of the sea-horses are coloured like the seaweeds among which they live, and the Zostera sea-horse that frequents the sea-grass (a flowering plant) on the Florida Coast has a very inconspicuous dress of mottled olive-green.

Photo: John J. Ward, F.E.S.

RED SEAWEED (*Polysiphonia*), PRODUCING SPORES (Highly magnified).

Polysiphonia is a large genus of red seaweeds whose thread-like fronds are made up of several parallel tubes, hence the name "many siphons."

But protective resemblance reaches a climax in the Australian Phyllopteryx in which the spines and knobs of the head and body are drawn out into frond-like tags, often branched and wavy. Never was there a more betasselled horse! This form is also interesting from an evolution point of view, for the pouch is represented by a groove underneath the tail, a condition seen also in some of the pipe-fishes, which are not very distant relatives of the sea-horses.

What one would most like to understand is why the parental care is *paternal*, especially as the males are smaller than the females. One can understand that parental care is highly advantageous, but why such emphatic division of labour should have been insisted on is beyond us at present.

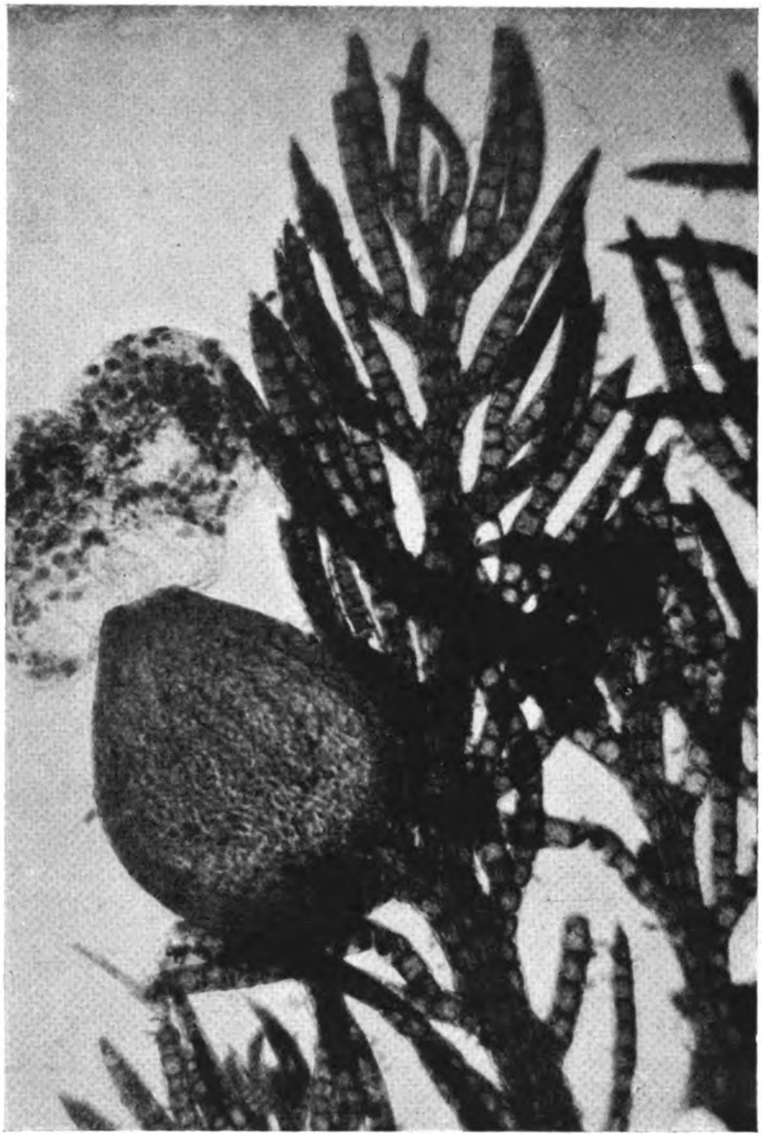


Photo: John J. Ward, F.E.S.

RED SEAWEED, (*Dasya coccinea*), DISCHARGING ITS SPORES.

This beautiful scarlet seaweed is not uncommon on some British coasts, about the low-water mark, and specimens are often tossed up in the jetsam. A thickish stem, with hair-like filaments rises from a disc-like anchor, and gives off slender branches with a feathery appearance.

Jetsam

The sea has such an "abundant progeny," to use Spenser's phrase, that even the jetsam, fortuitously tossed up on the beach, is often multitudinous. Sometimes the organic wreckage is very mixed—seaweeds and shells, battered birds and far-travelled fruits, wrenched-off zoophytes and stranded jellyfishes, empty eggshells, and clean-bleached skeletons. Another day it is very rich in a few kinds of things, as if the scouring of the floor of the sea had been restricted to some particular line or to some particular depth. Sometimes the sand is strewn with delicate, well-worn shells of the heart-urchin (Echinocardium); another day it is littered with the brown, plant-like fronds of the sea-mat (Flustra), the subject of Darwin's first scientific paper. On another occasion a great fleet of jellyfishes has come ashore, or again there are hundreds of scallops making the beach extraordinarily beautiful. Next week there are no scallops, but their place is taken by clams. There are times and seasons, no doubt, determining the character of the jetsam; but the diversity is to a considerable extent fortuitous, depending on the changing currents and winds. This diversity makes the strewn beach very interesting. One never knows what will turn up.

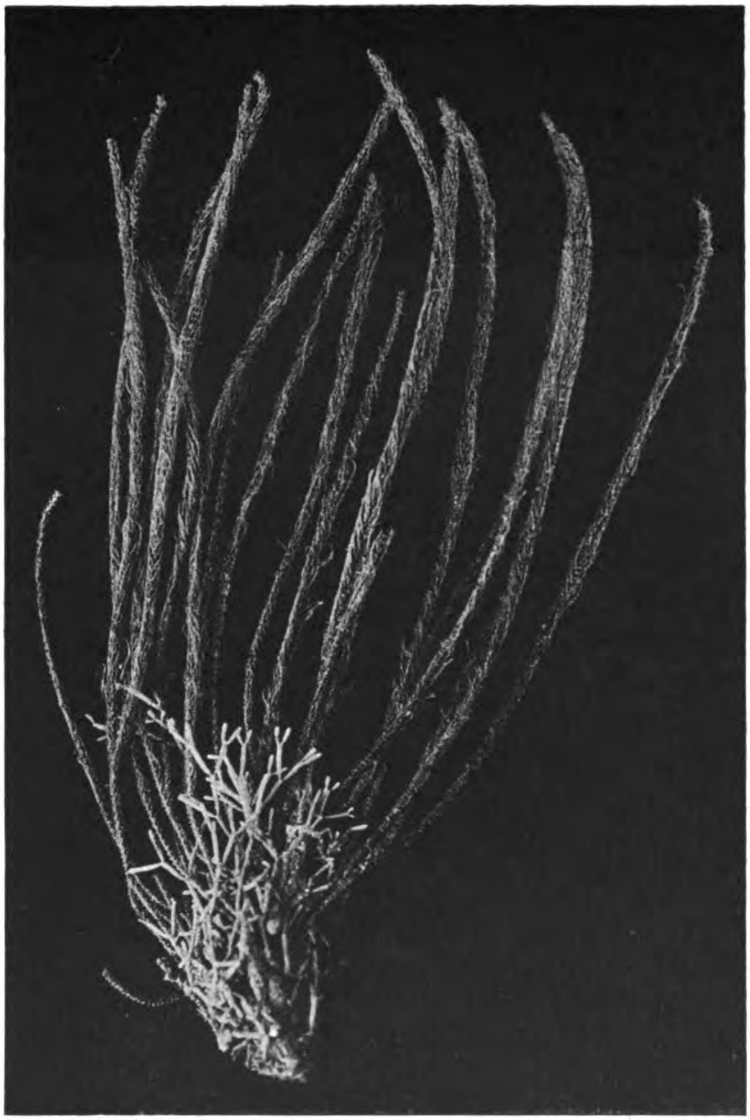


Photo: E. Step, F.L.S.

LOBSTER-HORN ZOOPHYTE (*Antennularia antennina*).

This is a common zoophyte or hydroid colony, belonging to the family of Plumularians. Each of the fixed stems, somewhat like a lobster's feeler or antenna, bears a large number of polyps in small cups. The appearance of the whole is somewhat plant-like.

feature of the jetsam is the abundance of whelk or "Buckie" egg-capsules. They occur in clusters from the size of an orange to the size of one's head, and have been wrenched off rocks or stones on the floor of the sea. Each capsule is a tough yellowish bag, and contained, to begin with, about 500 eggs. But for some reason or other one embryo out of a hundred develops more quickly than the rest, and proceeds to feed on them. The leaders devour the laggards, and are thus enabled to continue their development within the capsule without any food from outside. They continue developing and growing from autumn till spring, and by that time the whelk-shell is formed in miniature. In the course of years this shell becomes large enough to be held to the child's ear, forming what is called a "sympathetic resonator," that is to say, selecting and reverberating with certain of the sound-waves which in most places are always passing more or less unnoticed through the air. The clusters of egg-capsules that are torn off and thrown on the shore in autumn show the yellowish eggs inside, but those that are tossed up in spring are empty and so light that the wind blows them along the sand. If we look to the inner surface of one of these capsules, we see that an aperture has been made. This is where the survivors or the survivor cut through the capsule-wall and escaped. We see, then, that there are many points of interest in this common item of the jetsam, but its sharpest point is in illustrating the sternest and crudest mode of the struggle for existence, namely, cannibalism in the cradle.

The jetsam often includes traces of man's handiwork, in most cases ugly, but sometimes appropriate, and now and then with a suggestion of the drama of life. There lies an ugly old shoe, quite out of the picture; but there is a float-cork from a fishing-net which we recognise as not out of place; and there again is part of a broken oar that makes our imagination tingle. But what we wish to do is to take a few samples of the non-human jetsam.

In the autumn especially a very characteristic

Another kenspeckle object is a four-cornered

black purse—the so-called "mermaid's purse"—which is the empty shell of a skate's egg. It is made of the same material as our finger nails (horn or keratin), and is formed by the coalescence of fluid jets from a large gland in the middle of the oviduct. The eggs of skates are laid on the floor of the sea, and as they develop with extreme slowness, sometimes for a year in an aquarium, they require to be well protected. Hence the mermaid's purse. When the young skate, fully-formed in miniature, has exhausted its legacy of yolk and is ready to emerge, some secretion acts as a solvent on one end of the egg-shell, and the little creature struggles out through a gaping aperture. Thus the purses we find among the jetsam are almost invariably empty. It is interesting to learn that the egg-cases of the various species of skate differ from one another in detail. Those of dog-fishes are yellowish, and have a long tendril at each corner, by means of which they become attached to zoophytes and other fixed objects in the sea.

It is interesting to sit down on the dry sand at high water mark, and name a dozen "common objects of the seashore," which we can find within arm's length. There we see the skull of a guillemot with its sharp-pointed bill, the lower jaw of an angler-fish with its hinged inward-bending teeth, a fish vertebra shaped like a double egg-cup and showing very beautifully at its ends the ripple-marks of growth as concentric lines in the substance of the bone, the transparent pen of a squid, which seems to be the last relic of an ancestral shell, a crab's moult falling into an upper and a lower half when we lift it and disclosing the tendons which the tenant has left behind, the iridescent sea-mouse (technically Aphrodite), which we know to be an Annelid worm with a felt-work of bristles like rainbow splinters covering its back, a rope of sand which another of these annelids (*Lanice conchilega*) forms as a protective encasement, a dainty little building of lime, like a coral in miniature, which is made by one of the Moss-animals or Bryozoa, among which the sea-mat is also ranked. Much lower in the scale is a zoophyte or Hydrozoon colony, that deserves its name of "bottle-brush"; that strange,

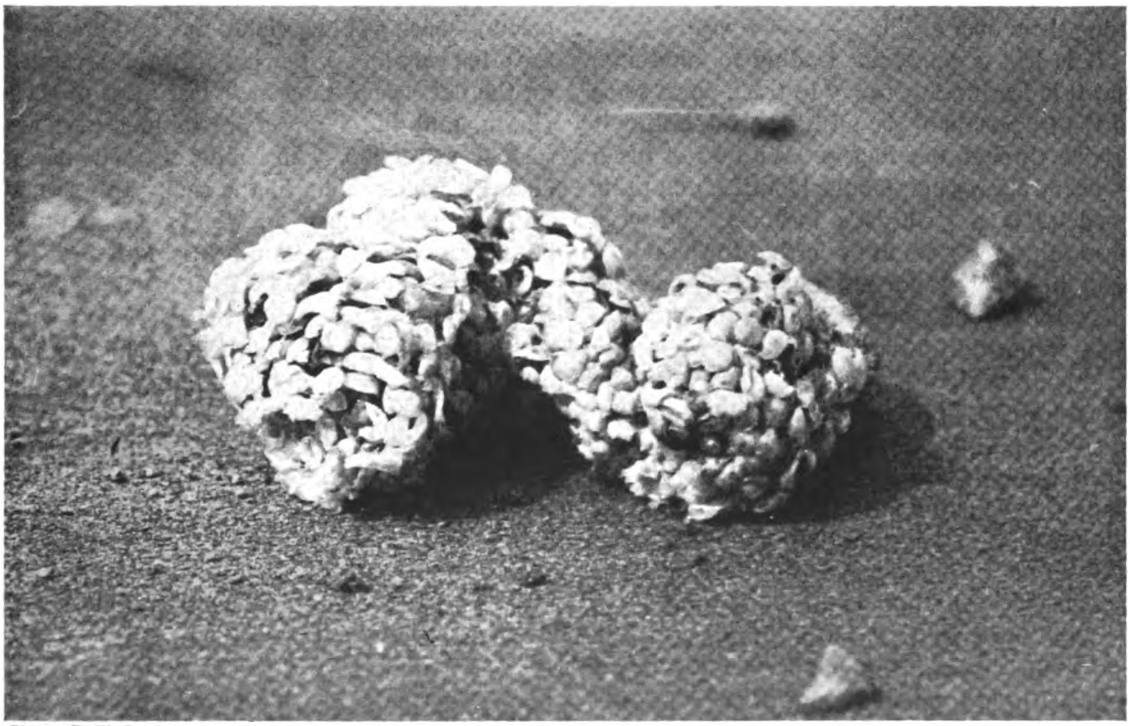


Photo: F. W. Bond.

CLUSTER OF EGG CAPSULES OF THE LARGE WHELK (*Buccinum undatum*).

Common on the seashore are the empty egg-capsule of the Large Whelk or "Buckie," the shell of which may be six inches long. It is the shell that children hold to their ears. Each capsule may contain 500 eggs and the cluster of capsules may be as large as a turnip. But only a few of the eggs develop, as those larvæ that are quickest in development devour the laggards. When the young whelks in the capsule reach the stage of having a small shell they file their way out.

dried object with many little apertures is a shrivelled colony of Dead Men's Fingers, distantly related to corals ; there is a big piece of sponge of the kind known as "mermaid's gloves"; and that oyster-shell is riddled with little cylindrical holes which are bored (or perhaps we should say dissolved out) by a minute sponge called Cliona. The substantial shell will gradually crumble to pieces and add to the sand on which we are sitting.

From the cleanest stretch of shore in Britain, where for weeks and weeks at certain seasons there is not even a piece of seaweed to reward the eye, we have collected year after year representative samples of the sparse jetsam. We have thrown them into a large hexagonal horizontal case with a glass top, and the result in the course of time has come to be surprisingly interesting and at the same time beautiful. It is only a fortuitous concourse of *disjecta membra*, crumbs from the sea's richly-spread table, but it is strangely eloquent. The contrast with man's jetsam is striking, and so is the frequent suggestion of Nature's way of reducing materials to their lowest common denominator and then using them over again.

It is just a game, not leading to anything, but it is fascinating to try to track down some of the fragments of the unsifted sand, letting it trickle through our fingers. We do not mean the very clean sand, for the identification of its particles is a geologist's business, and very interesting too ; we are referring to the mixed sand in which there are many fragments of animals not yet dissolved or worn out of recognition. What do we see ? The fluted spine of a sea-urchin with just a glimpse of a beautiful zoned structure internally, some flinty spicules of a sponge quite big enough to be seen without a lens, a fragment of the paddle of a swimming-crab, the beautiful spiral shell of one of the Foraminifera (Polystomella), curiously suggestive of a microscopic Nautilus, delicate platelets which seem to hail from the test of our smallest sea-urchin (Echinocyamus), which is never over an inch long and is often not bigger than half a pea, minute fragments of zoophytes and moss-animals, tiny mollusc shells that we cannot lift except on a moistened finger, one of the little plates that make the rampart of an acorn-shell, and so on for hours. As we admitted, it is only a play, but it gives one a very deep conviction of the finish of Nature's workmanship and of the universal penetration of that quality we call beauty.

Speaking of beauty, we would rank the jetsam high. The shore is an unending beauty-feast, and of beauty there is never any surfeit. There is something floral in the red seaweeds, especially when we float them in a pool to see the branching of the fronds, and then in the opposite direction there is the stable architecture of all sorts of shells, with beautiful shapes, with pleasing lines of growth, with colours which often look like fixed flushes But between the pliant seaweeds and the firmly built molluscan shells what a gamut of beauty there is in the diversified jetsam of the sea. "So fertile be the floods in generation, so huge their numbers, and so numberless their nation."

There are no more beautiful Open Sea animals than jellyfishes, but to appreciate their beauty one must see them swimming. The disc pulsates rhythmically ; the tentacles and frilled lips float out behind with graceful, twisting movements ; the translucent colours—such as blue, violet, red, and orange—are often very fine. When jellyfishes are stranded on the flat beach, they have lost most of their charm, and those preserved in museums are seldom attractive. In spite of their name, Medusæ, which refers to the snaky tresses and suggests something terrifyingly Gorgon-like, jellyfishes are extraordinarily decorative.

Jellyfishes.

The great majority of jellyfishes are *pelagic*, that is to say, they frequent the surface waters of the open sea, but a few have colonised the abysses, and some live near the bottom in shallow water. There is an unusual kind, called Cassiopea, common in harbours in the East Indies, that lies *on its back* on the sea-floor, remaining for hours or days at one place. It has a very stiff bell, which in some species bears a sucker-like dimple where it touches the ground. The concave surface of the bell is turned upwards, and instead of a proper mouth there are numerous pinholes on the eight or more branched and frilled lips. As these lips are often greenish or reddish, they are suggestive of seaweeds. But we do not dare to say that this resemblance is of any use.

Our commonest jellyfish, *Aurelia aurita*, of a

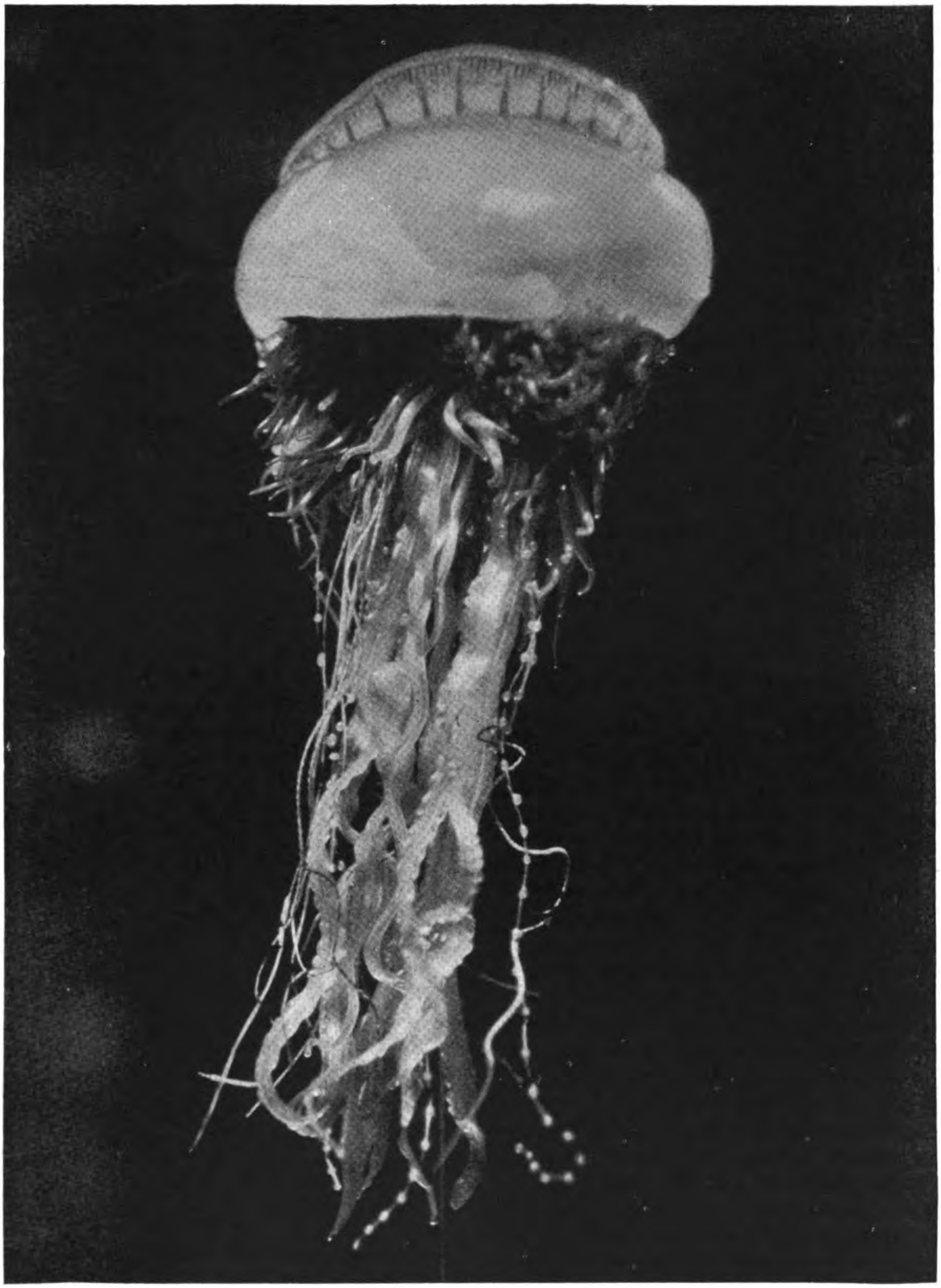


Photo: W. S. Berridge, F.Z.S.

"MAN OF WAR" (*Caravella caravella*), FROM THE WEST COAST OF AUSTRALIA.

This beautiful colony is related to the Portuguese Man of War. At the top there is a float that may be a foot in length, whereas that of Physalia is about five inches. Below the float or bladder there are numerous individuals showing much division of labour—some nutritive, some locomotor, some tactile, and some reproductive. It belongs to the order Siphonophora.

Photo: W. S. Berridge, F.Z.S.
MEDITERRANEAN JELLYFISH (*Carmarina*).
This beautiful jellyfish, one of the Trachomedusæ, common in the Mediterranean and other seas, shows four long tentacles and a central mouth hanging down like the clapper of a bell. It swims by contracting the disc or umbrella and driving the water out. It lives in the open sea near the surface.

blue-violet colour, is often about the size of a soup-plate, but it is small compared with many. Thus the amber-coloured Cyanea, sometimes so common that it breaks down stretches of salmon stake-nets in the shallow water along the shore, often has a disc a yard in diameter—quite big enough for a mermaid to sit on. The tentacles float out behind for a distance of many yards, and they are to be avoided by bathers, since their myriads of stinging threads are strong enough to pierce the human skin. The beautiful blue "cornflower jellyfish," *Cyanea lamarcki*, is perhaps just a colour variety of the amber-coloured "hair-jellyfish," *Cyanea capillata*, but it never grows so large. On the other hand, an Arctic variety or species, *Cyanea arctica*, must be the longest of all backboneless animals, for one has been measured with a disc seven and a half feet in diameter and tentacles 120 feet long! It is plain that the only possible home for such an animal is the open sea, where its huge bulk is supported buoyantly and where there is nothing to knock against. We may notice here that one of these enormous jellyfishes, with its tentacles swaying in the water, might readily form the basis for a sea-serpent story.

All jellyfishes are carnivorous. They depend a good deal on small open-sea crustaceans, which are present in inexhaustible abundance, but some devour the floating eggs of fishes and also the fry. Many feed greedily on smaller medusæ, and also on swimming-bells or medusoids, which are not nearly related. There is undoubtedly a wide range of possible food, including, in the case of the mouthless Rhizostomes already mentioned, very minute organisms. It is of interest to notice that the largest jellyfishes are those of the cold seas, a fact to be connected with the increasing abundance of minute surface creatures as we get further away from the Equator. One reason for this seems to be that life is less intense, more drawn out, in the colder waters, and thus more generations are represented

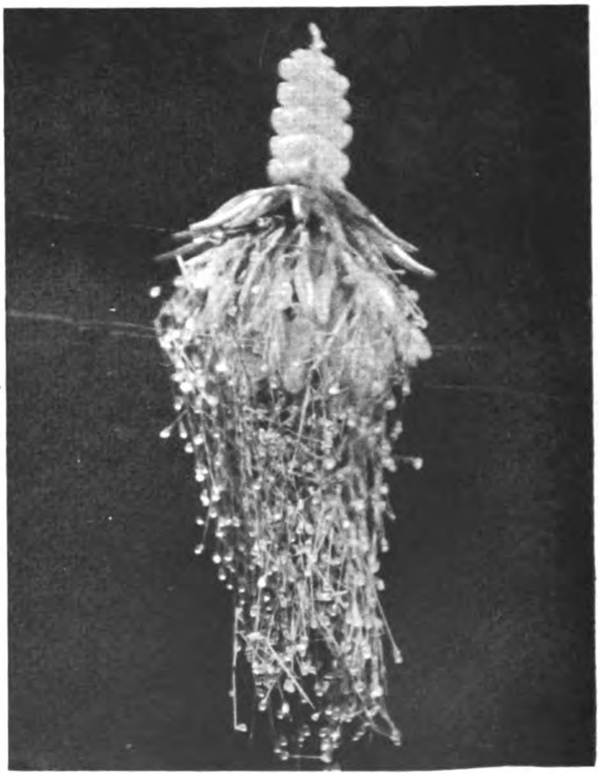


Photo: W. S. Berridge, F.Z.S.
MEDITERRANEAN SIPHONOPHORE (*Physophora hydrostatica*).
This is a beautiful colony, belonging to the same order as the Portuguese Man of War. Below a float or bladder at the apex there are rows of swimming individuals. Below these there are crowded whorls of other kinds of individuals, affording a fine instance of division of labour.

simultaneously. Hence our northern fisheries, for they depend in the long run on the abundant supply of very small open-sea organisms.

When a jellyfish is rigorously starved it is able to live for a month or six weeks on its own jelly. Though most of the jelly is water, there is a small percentage of something organic, allied in composition to gristle or to chitin, and that something keeps life agoing. Of course the creature must get lighter and lighter every day and this happens according to a very regular law, that the loss of weight each day is proportional to the weight of the animal at the beginning of that day. Thus the less jelly there is the longer it lasts!

This seems an appropriate moment for noting that the Japanese eat jellyfishes—a dainty kind of repast. They take a kind of medusa called Rhopilema, and cure it with alum and salt, or between leaves of a sort of oak. Before being placed on the table the dried jellyfish is soaked in water, cut into strips, and flavoured according to taste. What chances we miss!

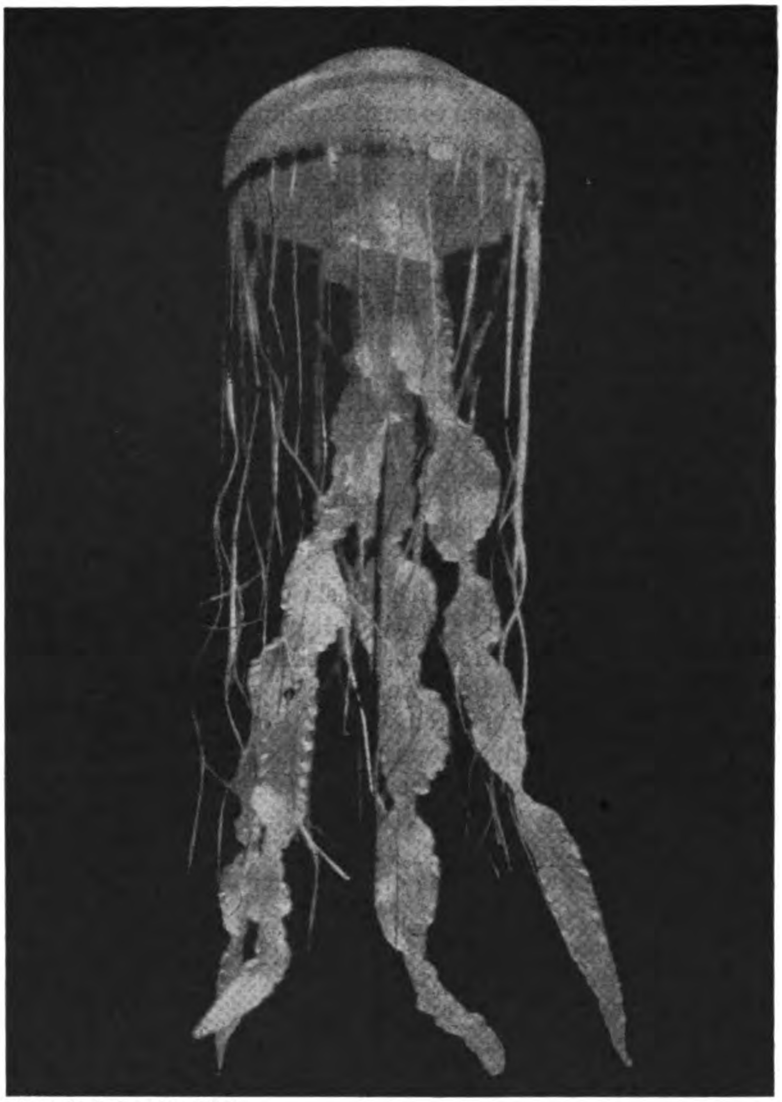


Photo: W. S. Berridge, F.Z.S.

NORTH ATLANTIC JELLYFISH (*Chrysaora isosceles*).

This Atlantic jellyfish is occasionally found off British coasts. It has a large mouth guarded by four long grooved lips. There are twenty-four tentacles round the circumference of the disc or umbrella, and in the same position eight stalked balancing organs or "statorhabs."

In capturing their prey, jellyfishes are helped by the countless stinging-cells on the tentacles and lips. When one of these cells is touched by an appropriate stimulus it explodes and jerks out a long lasso, which can often penetrate the victim's skin. The function of these "nettle-threads" is partly grappling and partly paralysing. According to some authorities the poison is formic acid, but the effects in certain cases suggest something more subtle. An interesting point is that a medusa may kill a fish of considerable size, and yet other fishes much smaller may enjoy immunity. They swim about under the shelter of the umbrella, in and out among the tentacles. Thus young whitings are often guests of the amber "hair jellyfish," and a hundred horse-mackerel may hide under a Rhizostome. The common companions are to be distinguished from predatory little fishes that nibble off pieces of the medusa, and often get caught in so doing. The stinging is sometimes virulent and the members of the Charybdeid family are popularly called "sea-wasps." They swim with unusual vigour and capture

fishes inconveniently large for their stomachs. In our yellowish or bluish Rhizostome, which may have a disc-diameter of a foot and a half to two feet, a shelter is given to small Amphipod crustaceans as well as to fishes. Here we may notice that besides the cosmopolitan Aurelia, which is found from pole to pole, the amber and blue Cyanea, the yellowish or bluish Rhizostome, there is another readily recognisable jellyfish in British waters, the Compass Medusa or Chrysaora. It occurs in a variety of colours, especially reddish-brown, and owes its popular name to sixteen radiating lines which split into thirty-two about halfway across the disc. It is peculiar in being male and female at once, or male when it is young and female when it grows older, for the rule among jellyfishes is to have separate sexes.

The fertilised eggs of a jellyfish are sheltered for a time in the niches of the frilled lips ; in typical cases they become free-swimming ciliated embryos, which soon settle down on rocks as fixed polyps. By a strange transverse budding the polyp or hydra-tuba forms "a pile of saucers," and one saucer after another tumbles off, growing rapidly into a perfect jellyfish. Thus the typical life-history of a jellyfish exhibits what is called alternation of generations.

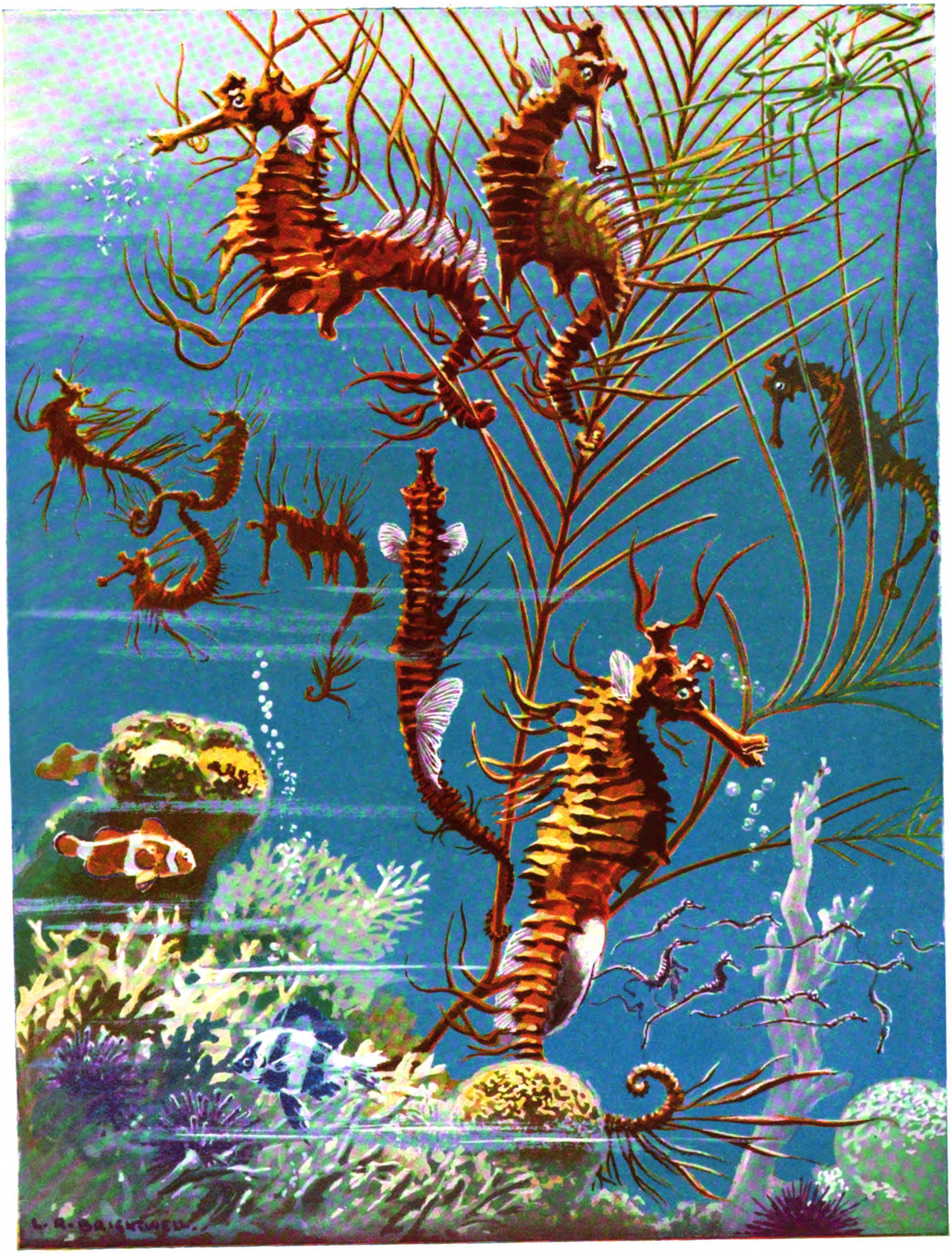
How beautiful the mode of swimming—by increasing the curvature of the umbrella and driving out a mass of water. Dr. A. G. Mayer says that sodium oxalate forms as a waste product in the pinhead sense-organs round the margin, that calcium chloride in the sea-water soaks in and precipitates calcium oxalate, setting free sodium chloride (common salt), which is a powerful stimulant for the nerve cells, causing them to command the muscles on the under-side of the bell to contract. How very interesting the sense-organs are, which we see so clearly in eight niches on the margin of Aurelia. Each is just a speck, but each includes a part sensitive to light-waves, a part sensitive to chemicals in the water, and, thirdly, a balancing organ. If the sense-organs are injured the jellyfish is no longer able to swim rightly.

The Herring

All fish is not the same fish ; they differ in temperament as they do in taste. And one of the most marked individualities is the herring, so familiar in its various disguises on the breakfast table. Perhaps the herring has not much of an inner or mental life, but it is an alert creature with keen senses. Compared with easy-going fishes like the carp, it is nervous and high-strung. It is not easy to keep the herring in captivity, for it will dash itself against the sides of the aquarium or jerk itself clean out of the water on to the floor of the room. Thus it has been found impossible, we believe, to transport living adults to distant seas, such as those that wash the coasts of New Zealand.

One cannot rightly appreciate the herring without seeing it alive, which means an excursion on a fishing boat. To see the net drawn in is a feast to the eyes—the meshes seem to be full of broken rainbow. There is silver and gold, steel-blue and lustrous green, and hints of other colours. Many of the herring, caught by their gill-cover, are dead—drowned indeed—when the net is drawn in ; but this is not true of all, and the live herring is unforgettable. Another feature that strikes us is the litheness of the body. As in other fishes of active habits, the portion of the body given over to locomotion is a very large fraction of the whole. It is well known that the paired fins of fishes are almost always balancing organs, and that the posterior half of the body, which is mainly sheer muscle, is the organ used in the rapid sculling by which most fishes swim. The herring's body is stiff indeed on the fishmonger's slab, but in the water it is even more than what Ruskin called "a twisted arrow." We cannot find any comparison save with some other consummately active creature, like a bird. The creature's stream-lines, so well adapted like those of a yacht, for swift movement through the water, are quite unsurpassable. Beauty of colouring, beauty of form, beauty of movement—we have them all in the herring !

When herrings play about in a shoal near the surface they "make a ripple," as the fishermen say, as if there were a slight breeze ; and the sound of their going can be heard for a short distance when everything else is still. Their movements in the darkness are marked by bright light, which many fishermen and some naturalists believe to be due to the herring itself. For our part, we do not think that the herring has any



Specially drawn for this work by L. R. Brightwell.

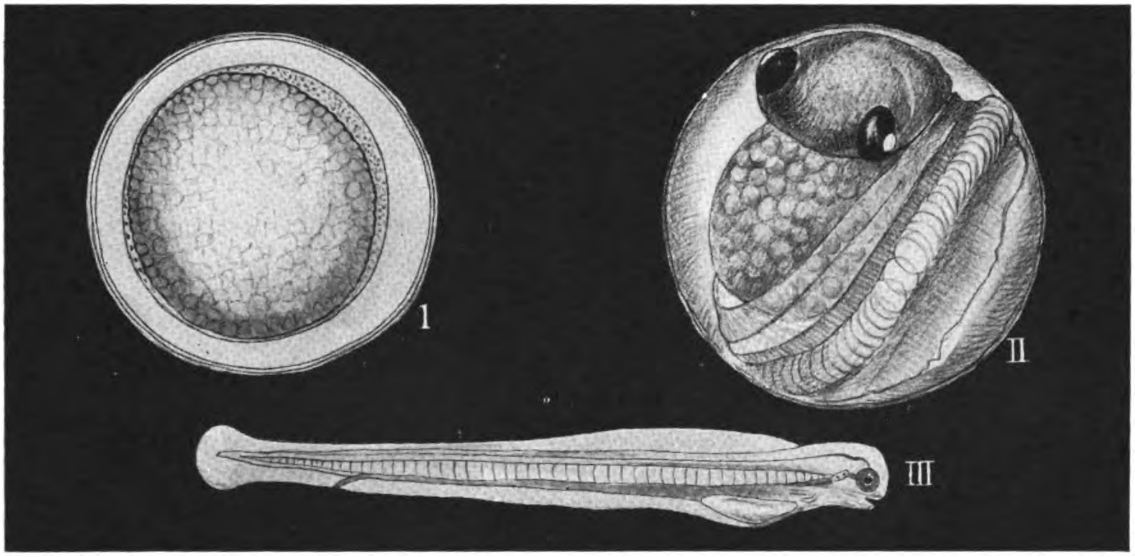
AUSTRALIAN SEA-HORSES (*Phyllopteryx eques*).

This whimsical fish differs from the European Hippocampus in having long skin tags growing from the knobs and spines on the head and body. These give it a protective resemblance to the seaweed amongst which it lives. The drawing shows an upper specimen to the left eating the free-swimming larvæ of barnacles, and below to the right a male is liberating young ones from his brood-pouch. In the centre is a back view, showing the quivering unpaired dorsal fin. The strange attitudes are well depicted.

luminescence of its own. The light is surely due either to reflection, or to contact with small open-water animals, many of which are "phosphorescent." The glowing light seen on herrings hung up to dry is, of course, produced by luminiscent bacteria.

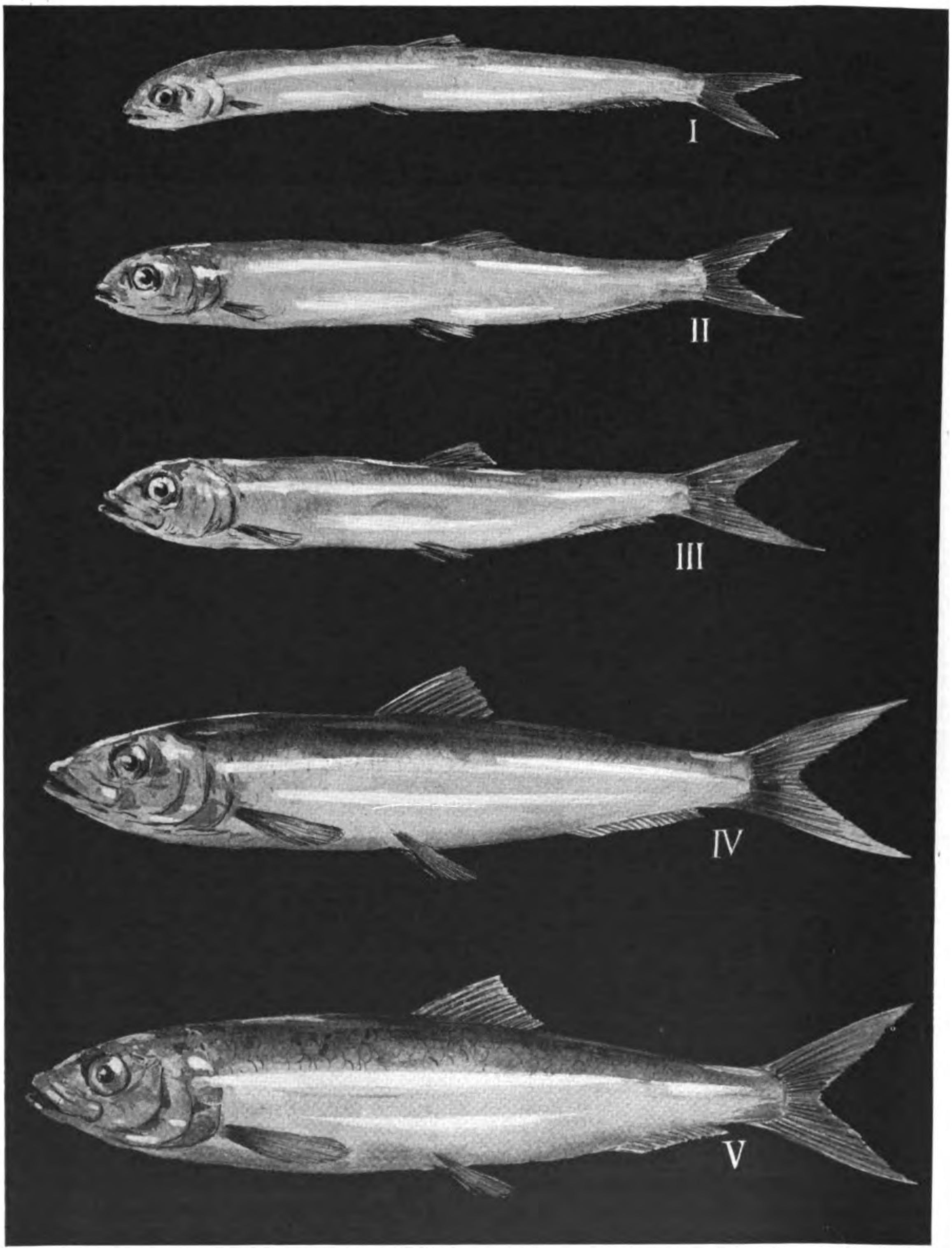
There are over fifty different species of the herring genus; and of *the* herring of the North Sea and the North Atlantic there are several *races*, which are as much disputed about as the races of mankind. The herring, like man, is diffusive, exploring every niche of opportunity, and in the various quarters of the fenceless sea different varieties or races have established themselves. Thus the dwarfish Baltic herring are very different from the splendid fish from the West of Scotland, which are sometimes over a foot long. But they are all fertile with one another, just like human races; and as they are given to wandering, there have arisen baffling racial mixtures, just as in mankind. But there seems to be a well-marked distinction in certain cases, for instance between the "summer spawners" of the open sea and the "autumn spawners," which keep nearer shore. Those Rip van Winkles who do not believe in evolution should study the splitting up of the genus Herring or Clupea into species (like herring, sprat, pilchard or sardine, and shad), and the splitting up of the herring species (*Clupea harengus*) into its sub-species or races. Evolution is going on.

Herrings have no armour or weapons; they have a multitude of enemies who enjoy their palatability—cod and coalfish, shark and rorqual, seal and cormorant; they have no great equipment of brains; *how, then, do they hold their own in the struggle for existence?* Part of the answer may be found in their alertness and swiftness, but a great part is to be found in their capacity for prolific multiplication. They succeed not because they are strong or clever, but because they are many. A female herring may produce 20,000 to 40,000 eggs, not very many as compared with cod and conger, which run to millions, but enough. There is a considerable margin for safety. Moreover, the eggs do not float, like those of most of our food-fishes; they sink when they are liberated, and they are glued to stones and the like on the floor of the sea. There is great excitement at the spawning time, when shoals of herring seek shallower and sometimes less briny waters. Gregarious in its feeding habits, the herring is gregarious likewise in its multiplying. In a frenzy, lasting for five or six hours, the females liberate their ova, and



EARLY DEVELOPMENT OF THE HERRING (after Hoek).

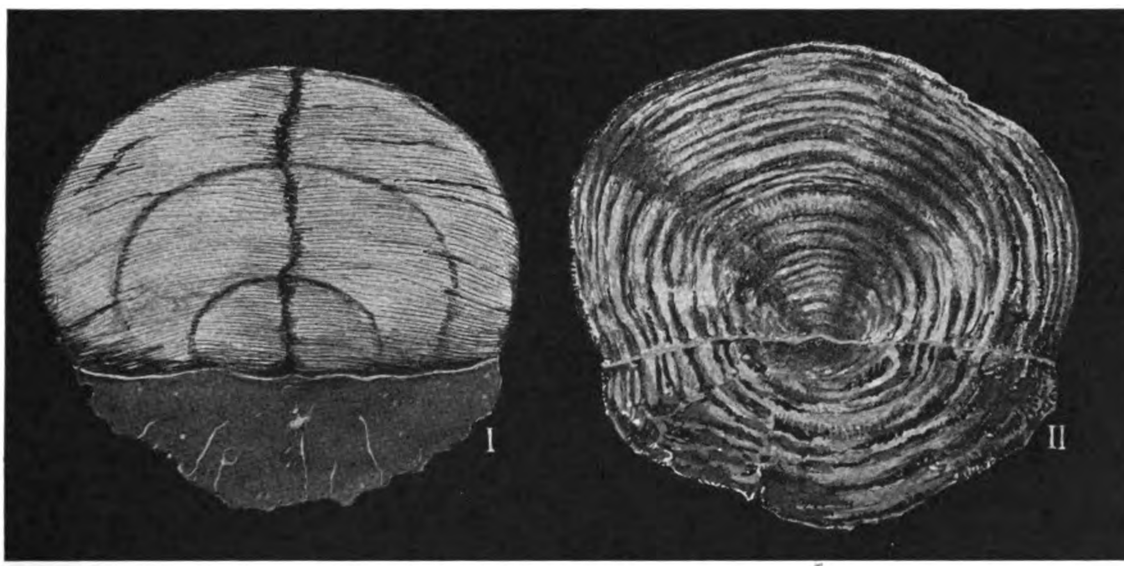
1. The fertilised egg that has begun to develop; much magnified. It is a transparent sphere, about one-sixteenth of an inch in diameter. 2. The developed egg, six days after fertilisation, with an unhatched embryo, showing the eyes on the head and the body twisted round what remains of the yolk. 3. A young larva still living near the bottom of the sea, about two-fifths of an inch in length. It will soon rise to the mid-waters and then to the surface.



SOME STAGES (1-5) IN THE GROWTH OF THE HERRING.

the males the fertilising milt. The sea becomes greyish and a rank smell of herring rises from the surface.

Enormous crowds of young herring often frequent inshore and estuarine waters, where food is abundant ; and these furnish a great part of the toothsome dish known as " whitebait." Of course that sometimes includes, very naturally, young fishes belonging to other species, e.g., sprat ; and there is a well-known tale of one of the British Museum ichthyologists who distinguished eight species on his dinner plate ! The herring is a dainty feeder, depending mainly on small open-sea crustaceans—hence the delicious flesh. It is a gregarious creature, fond of company. It is intensely alive, and sometimes leaps into the air. Following its food, it roves far and wide, and up and down ; it also " migrates " in search of suitable spawning ground, or because of many enemies, or because the waters have become oily and foul. The herring is a nomad and one of the most successful of fishes. We wish we knew it more intimately.



HERRING SCALES.

Three scales of a herring showing lines of summer growth and winter check, from which the age of the fish can be determined. The anterior part of the scale with an even contour lies embedded in a skin-pocket ; the posterior part of the scale which protrudes and overlaps the next one behind, has a fringed contour and lacks the fine striped pattern.

On a voyage to the Cape or India or even America, it is no uncommon sight to see flying-fishes rising in front of the steamship's bows and skimming to either side high above the waves. Now and again one of them lands on the deck or dashes in at a port-hole. In some cases there is a swarm of these beautiful creatures, reminding us of insects rising in front of us when we walk in a meadow in a warm country like Italy. When the sun shines on them they look like big dragon-flies, and there is much point in what Ibanez says in his novel, " Mare Nostrum " (Our Sea) : " Before the prow hissed the silken wings of flying fish, spread out in swarms, like little squadrons of diminutive aeroplanes."

Flying Fishes.

After much discussion most naturalists have come to the conclusion that in the ordinary Flying Fishes of the sea (Exocœtus and Dactylopterus) the enlarged fore-fins serve as *parachutes* not as wings. They may vibrate a little in the first case, and flutter a little in the second, but they do not in the strict sense strike the air. The impetus is due to strong strokes of the tail before the fish leaves the water, and it may be increased by the force of wind and wave. When the fishes sink to the surface of the water again, they may lash out afresh with the tail and make another start without the body being immersed. They may repeat this performance at short intervals. It should be noted that the muscles of the pectoral fins, though somewhat more developed than usual, are not very strong, and that in

ordinary fishes the paired fins are not for swimming but for balancing the body.

Some recent observations by Dr. E. H. Hankin throw a fresh light on the aërial locomotion of Flying Fishes. Much depends on the atmospheric conditions. In the Arabian Sea on a very still evening after sunset he noticed that the Flying Fishes did not glide in the air for more than a yard. They were also very liable to lateral instability or side-slip. On other occasions when there was sunshine and a light breeze the flight extended for 200–400 yards. As with " sailing " birds, a breeze is essential for successful " flight." The fore-fins are usually held " flat," that is, in a horizontal plane. Sometimes they are slightly inclined upwards. Now the soaring vulture has its wings in the " up " position for slow-speed flight and in the " flat " position for high-speed. In rare cases the fish had its fore-fins inclined very slightly downwards, and this " down " position is probably used for flight at the highest speed. It will be remembered that by " sailing " or " soaring " in birds is meant that mysterious kind of flight in which there is rapid progression without any apparent strokes of the wings.

Dr. Hankin also noticed that the extreme tips of the fore-fins may be bent up at an angle of forty-five degrees to the rest of the fin, and the same appearance is seen in the wing-tips of vultures in their horizontal sailing flight. This is another fact pointing to the conclusion that the " flight " of the Flying Fish has something in common with the " sailing " or " soaring " of albatross and vulture. There may be flapping of the fore-fins at the start, but not after the fish has got well under way. A speed of over ten yards per second was observed, the fish keeping up with the vessel for eight seconds. The maximum rate is probably about twenty yards per second.

By careful observation of species of flying fish that have coloured hind-fins, Dr. Hankin was able to show how the fish checks its velocity both in high-speed and low-speed flight by altering the position of these fins.

In one species that has the hind-fins small and far forward, therefore unsuitable for checking speed or for vertical steering, the fore-fins are drawn back through an angle of about forty-five degrees when the fish reaches the end of its flight. The result of this is that the fish makes a nose-dive into the water without altering its speed.

The Storm-Petrel.

Amongst the jetsam which November gales toss up on the beach we sometimes find a battered Storm-Petrel, and once we found its cousin the Fork-tailed Petrel which had met a similar fate. From their breeding-places, which are often on islets to the north and north-west of Scotland, Storm-Petrels migrate in autumn to the open sea, where they spend the winter. It is probably during these migrations that some of them go astray in stormy weather, and are killed against the rocks. More independent of the earth than almost any other bird, for they rarely touch it except at their nests, the petrels are often wrecked in the end.

They get various names, these creatures of the open sea, smallest and daintiest of our web-footed birds, one of the best known being Mother Carey's Chickens, which is supposed to suggest that the Mater Cara, who has the weak and storm-tossed in her keeping, has a kindly interest in the adventurous petrels. And as to the word petrel, it is supposed to refer to St. Peter's attempt to walk on the water.

The Storm-Petrel is a sooty black bird, with a little white about the tail and under the wings, just over six inches in length, with long, somewhat swift-like wings well suited for rapid flight, and with long legs, the meaning of which is obscure. That its affinities are with albatross, shearwater, fulmar, and the like, and in nowise with the gulls, in spite of superficial resemblances, is indicated by the fact that the horny bill is made up of numerous pieces (taking our thoughts back to reptiles' scales), by the extension of the two nostrils into a double external tube, by the single chalky-white egg with a few reddish-brown spots, by the very long sooty-ash down covering the nestling, and by many deeper characteristics.

The Storm-Petrel has become a thoroughgoing pelagic bird ; that is to say, it keeps to the open sea except at the nesting-time. It has actually been seen flying across a promontory and hawking insects like a swallow, but this is not typical. Usually it flies close to the waves with its web-feet touching now and then, or paddles about floating on the surface. Its food consists of small fishes, crustaceans, molluscs, and other open-sea animals, and at the nesting-time it seems to be fond of morsels of sorrel. The crop contains a good deal of oil, which the bird vomits up forcibly

Photo: H. M. Salmon.

GANNET (*Sula bassana*) SITTING.

The mature bird is mostly white, tinged with buff on the head and neck. There are dark quills on the wings. The total length is just about a yard, and the expanse of wing exceeds six feet. Its flight is masterly and its dive may begin two or three hundred feet above the water.

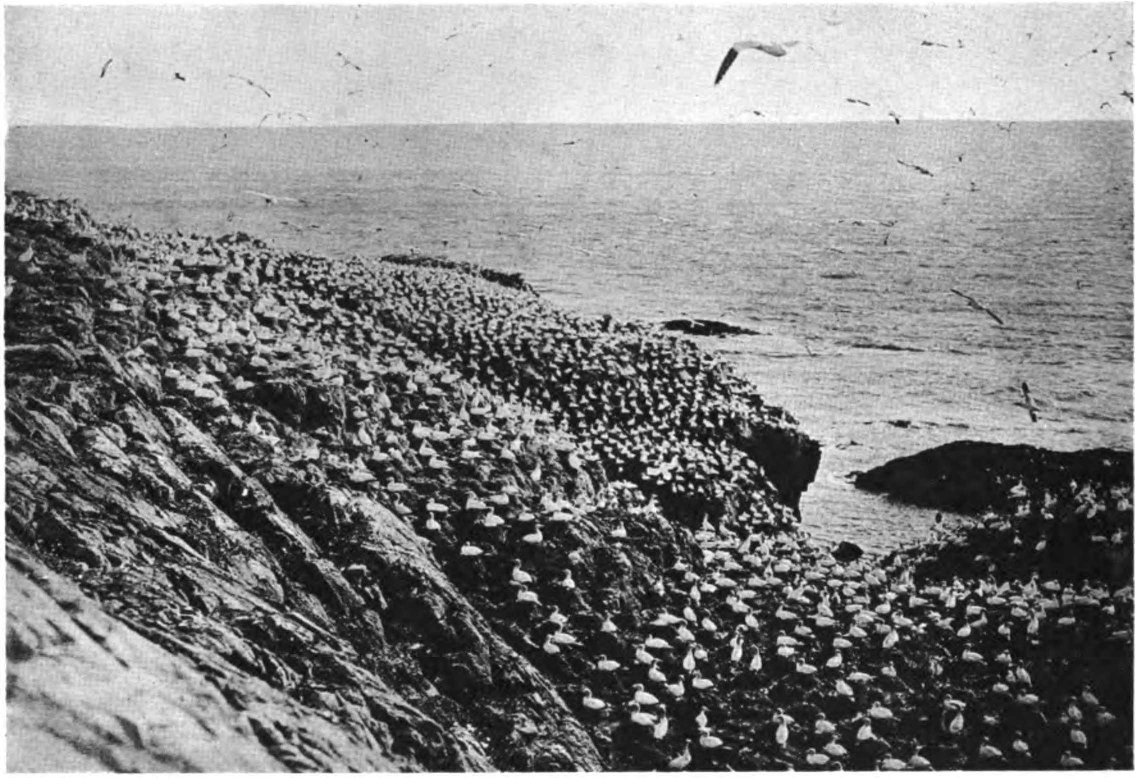


Photo: H. M. Salmon.

A GANNET COLONY.

Most of the Gannets go out to sea after the breeding season, and often travel far in search of fish. Thus the breeding haunts are relatively deserted in winter, and sometimes entirely for a few weeks. The thronging multitudes return to the cliffs in March and April and leave again in September and October. There may be many thousands, and the rocks become whitewashed with their droppings.

when suddenly molested, which is also given by both sexes to the young. A captive Storm-Petrel was fed for three months on oil alone. The amount of oil throughout the bird may be inferred from the fact that some islanders thread a wick through the dead body and use it as a lamp, "the excess of fat burning steadily until the whole is consumed."

The Storm-Petrel's nest hardly deserves the name; it is never more than a little mattress of dry grass. The single egg is laid (about the end of June in Scotland) in a hole among the rocks or loose stones, or in a burrow, which may be a rabbit's, or may be partly made by the bird's own exertions. There is a pervasive musky smell about the hole. The parents seem to share the patient duty of brooding, and this lasts for about five weeks. During that time the birds are not seen coming or going, for they become crepuscular in their habits. After the young bird is hatched it seems to be left alone during the day while the parents recuperate at sea and collect the oil for the heavy supper which their nestling makes, and needs. It is not till the autumn that the young birds are able to leave the hole and fend for themselves, and such a prolonged infancy would not be possible were not the nesting-place well hidden.

There is no doubt that the Storm-Petrel belongs to a family of ancient birds, with a long pedigree going far back to some affiliation with the extinct, giant, toothed Diver of the Cretaceous times. Like its relatives, it has held its own by becoming highly specialised in its every-day habitat and in its way of feeding on surface pelagic animals. It is very interesting to find among its relatives a Diving Petrel (Pelecanoides), remarkably but deceptively like a Little Auk, which has become a most expert diver, disappearing instantaneously, swimming swiftly with its wings under water, and emerging again *in flight*—a brilliant instance of the way in which survival is secured by trying every niche of possibility. A great part of organic evolution has been a continual obedience to the precept: Test all things and hold fast that which is good.

There is in many living creatures a quality of inventiveness, of more or less intelligent but always strenuous experimenting, which enables them to evade the closing net of environing difficulties. Often, at least, their reward is survival through originality.

The Gannet

We take the gannet (*Sula bassana*) as a type of Open Sea birds, for its summer stations, like the Bass Rock (to which it owes the name bassana), Ailsa Craig, Bressay, and Suliskerry, are breeding places, not homes. A few "old stagers" may be seen at these breeding haunts in winter, but the great majority migrate to the open waters of the North Atlantic. A number find their way into the Mediterranean and the Gulf of Mexico. An interesting point is that there are now only fifteen breeding stations, and that six of them are round the British coasts. The gannet, or solan goose, is the only British representative of its family (Sulidæ); it is related to Tropic Birds, Frigate Birds, Cormorants, and Pelicans; but not in any way to geese.

Among structural peculiarities may be noticed the closing of the nostrils to a pinhole, the vestigial state of the tongue, and the inclusion of all the four toes in the web. There is a curious comb-like serration of the claw of one of the toes, comparable to the "pectination" seen in nightjar, heron, bittern, and some other birds, but its significance is uncertain. More interesting is a forward tilting of the coracoid bone of the shoulder-girdle, so that it is almost in a line with the axis of the breastbone. This makes it easier for the bird to stand the impact of its terrific dive. Another peculiarity, very well known but not very clearly understood, is the presence of a large number of air-sacs underneath the skin. They are in connection with the internal air-sac system characteristic of birds, and can be inflated or emptied from the lungs. They form a layer of air cushions over the

Photo: H. M. Salmon.

PART OF THE GANNET COLONY.

There are about fifteen breeding stations for the Gannet, and six of these are British, e.g., Ailsa Craig and the Bass Rock. The others, beyond Britain, include the Faëroes and Iceland, and some islands off the East Coast of North America. In winter most of the gannets are on the open sea.

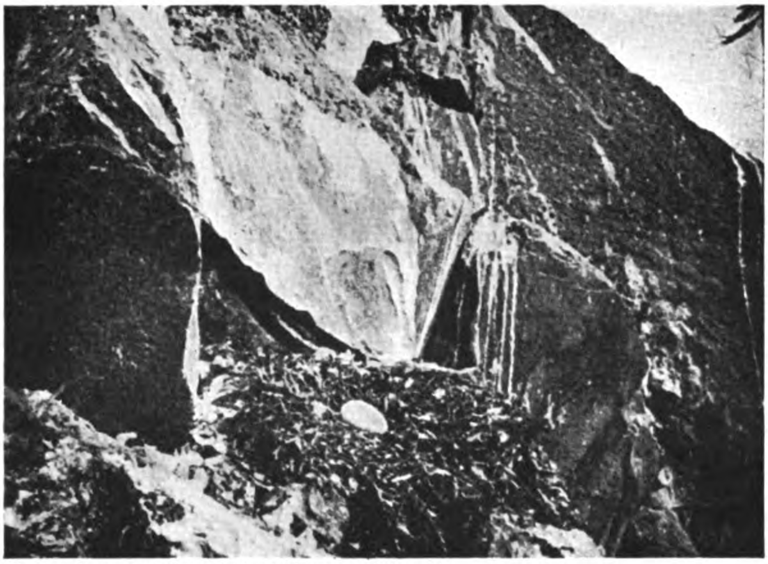


Photo: By courtesy of the British Instructional Films, Ltd.

THE NEST OF THE GANNET.

The nest is on a shelf or bracket of a sea-cliff. It is made of seaweed, turf, or the like gathered from the cliff; but it is decorated with "all sorts of odds and ends"—even candle ends! There is a good deal of thieving and squabbling during the nest-building time.

not nearly at an end of the gannet's. But it may be enough to notice one more—the long, strong, sharp-pointed bill with a row of fine backward-directed serrations along the inner edge. Nothing could be better for gripping fish.

Gannets are hungry birds, and do not obey hard-and-fast rules; but there is no doubt that they seldom catch anything but fishes, except an occasional squid; that they prefer full-grown herring and mackerel and the like; and that they look out for shoals, for that makes fishing easier. As their booty is moving even as they dive, we can understand the importance of not closing the wings till the last moment in the descent. It sometimes happens that they swallow somewhat difficult fishes like the gurnard—a thorny subject. This may be fatal. Dr. F. M. Ogilvie notices that gannets, like some other Open-Sea birds, suffer severely in

greater part of the body, and are very conspicuous when one skins the bird. They were studied long ago by Sir Richard Owen, Professor MacGillivray, and others, but their meaning is not quite certain. They make the heavy body more buoyant when the bird is floating in the stormy sea; they may serve to lessen the shock of the great dive; and we venture to suggest that they may have some use in winter in lessening the loss of heat into the cold water. It must be understood that they represent an exaggeration or great extension of the ordinary air-sac system, but there is a curious suggestion of a diseased state in man known as emphysema, a puffy condition due to the diffusion of air into the connective tissue. Lastly, it must be noted that a similar superficial extension of the air-sacs is seen in hornbills and screamers, whose habits are very different from those of the gannet.

Every creature is a bundle of adaptations, and we are

Photo: By courtesy of the British Instructional Films, Ltd.

NEST OF THE GANNET, SHOWING THE EGG DARKENED IN COLOUR BEFORE HATCHING.

The single egg has a chalky outer layer, but beneath this it is bluish-green. As brooding goes on, the shell usually becomes stained. Both parents build and brood, and the incubation period is six weeks. The brooding bird covers the egg with its feet or with one of them before it lowers its body on the nest.

prolonged stormy weather, for the fishes are driven beyond their sight and reach. "There is no bird, to my mind, that seems so full of vigour and the joy of living, when the world goes well with him, as a gannet, and no more pitiable sight than the same bird buffeting up against the relentless 'north-easter,' struggling on without food, without strength, and finally falling exhausted and being washed up by the incoming tide." On the other hand, the gannet has no living enemies except man. It may be that the bird's custom of accumulating malodorous heaps of disgorged fish near the nest is the beginning of a storing instinct. For were there not some food in reserve a prolonged storm would involve the nestlings as well as the parents in disaster. That brings us to family matters.

Photo: By courtesy of the British Instructional Films, Ltd.

THE NEWLY-HATCHED GANNET.

When just hatched the young are dark slate-coloured, but blind and naked. Patches of down soon appear, and these lead on to a thick fluffy white suit, as in the photograph. In a few weeks there are true feathers which gradually replace the down and give the young bird a dark brown dress, speckled with white. In this dress, when about three months old, the young birds leave the rock.

First of all there is the courting, of which a careful description has been given by Mr. F. B. Kirkman. Gannets are monogamous, and probably pair for life, for they are seen arriving in pairs at the breeding station. They have an elaborate ceremonial, wagging their heads, knocking their bills together like castanets, whetting one bill against the other, cosseting one another's plumage with their bill-tip, bending and bowing, and uttering strident cries, "Urrah, urrah." The males and females are alike in appearance, and behave in the same way. The ceremonial does not stop with the courting, but continues into the brooding chapter, and is exhibited when one bird relieves the other at the nest. Very remarkable is Mr. Kirkman's account of the ceremonious way in which the bird that has been sitting proceeds to leave the nest and the ledge of the cliff. It rises silently, stretches neck and beak up to the sky, raises its wings more or less erect, depresses the tail, walks stiffly to the edge of the shelf, and

Photo: By courtesy of the British Instructional Films, Ltd.

THE YOUNG GANNET ALMOST FULLY FLEDGED.

For a while the young Gannet gets its meals by plunging its head, and much more than its head, into its parent's enormous gape. When almost fully fledged it is predominantly a brown bird: by the time it is a year old there is much white; but four years or so are usually required for the development of the mature plumage.

launches itself into the air with a strange cry never uttered on any other occasion. There can be little doubt that the gannet is a very affectionate bird, and this is not inconsistent with a strange roughness which mates sometimes display to one another or with their snappiness to their next-door neighbours. There is considerable bickering on the craig.

The gannet stakes the continuance of its race on one egg per annum, which shows that its position in the struggle for existence is fairly secure. The shell is greenish-blue, covered by a rough, chalky layer, which is often stained. Before sinking down on the sparse collection of seaweed and flotsam that forms the " nest," the brooding bird puts its webbed feet over the egg and keeps them in this position. The incubation lasts for six weeks—an unusually long time—and the bird that is sitting is not easily disturbed. It may lunge at you with its bill, but it sits tight. It is perhaps the gannet's indifference to man's presence that accounts for the name " booby " (Portuguese for fool ?) applied to some other species of Sula, for the bird is anything but stupid.

The newly hatched gannet is blind and naked and slate-coloured ; but it is soon covered with beautiful white down. It is abundantly fed and becomes very fat, which may make for safety by inducing a sluggish disposition. For the ledge of a sea cliff is not a suitable place for juvenile exercises. In about three months the youngster is ready, but not very willing, for its first plunge. The prolonged feeding means a good deal of work on the parents' part, but they share responsibilities equally both in sitting and foraging. In early days they prepare pulpy packets of half-digested fish, sometimes thrown up and re-swallowed, and the young bird gets possession of these by thrusting its head into the parent's widely-opened mouth. Later on, the young bird takes fresh fish from the adult's crop, thrusting in the whole length of its head and neck. It must be a great day when the young gannet first catches a fish for itself. They are not mature for three or four years, and exhibit as they grow an interesting series of plumages. As the immature birds are seen among the adults on the breeding stations they have opportunities for picking up hints which may be useful additions to their heritage of instincts. For even a booby can learn.

Porpoises.

The first backboned animals to get a footing on dry land were certain Amphibians, and this happened in Devonian and Carboniferous ages. From ancient Amphibians there sprang Reptiles ; and from terrestrial Reptiles there evolved Birds and Mammals. But, as we have already pointed out, life on dry land was not easy, and so we find terrestrial animals seeking out other haunts if haply they may find some relief from the keenness of the struggle for existence. Thus some became tree-animals and others became burrowers ; some became flying animals and others returned to the sea. We take porpoises as good examples of the descendants of land mammals that harked back to the ancestral aquatic habits.

The distinguished physiologist, Professor Sir John Burdon Sanderson, once remarked that our delight in looking at a beautiful animal is often mingled with an admiration of its *fitness* for its particular habitats and habits. This wise remark applies well to porpoises and dolphins. Their swimming movements are harmonious and beautiful in themselves, and the curves of their body are very pleasing, but when we watch them or any other Cetaceans (whale-like mammals) we are unconsciously influenced by the fact that they are big bundles of fitnesses.

The shape of the body is admirably fit for rapidly cleaving the water ; the lines of the body are stream-lines like those of a yacht. Everything is done to reduce friction ; the skin is smooth, and there are no protruding structures like ear-trumpets. The tail is flattened horizontally, and turned into a propeller that shifts the water first to one side and then to the other, but a propeller that does not go round ! The fore-limbs have become balancing flippers. Almost all trace of hair has gone, but its place in retaining the precious animal heat is taken by the thick layer of non-conducting blubber, which also makes the Cetacean more buoyant. And when we ask what blubber is, we find that it is simply an exaggeration of the layer of fat (the panniculus adiposus) which is found in almost all mammals, the common hare being a familiar exception. The nostrils, united in a single blow-hole in toothed Cetaceans, are situated on the top of the head, and this helps breathing (inspiration and expiration) when the animal comes to the surface. Moreover, the nostrils are valved,

A SCHOOL OF PORPOISES.

Porpoises belong to the genus Phocæna, and the British species is *Phocæna communis*, a gregarious Cetacean, often about six feet in length, black above, lighter beneath, with 16 to 26 teeth on each half of each jaw, not sharp like the Dolphin's. It sometimes ascends rivers and has been seen in the Seine as far up as Paris. Its gambolling movements are very beautiful.

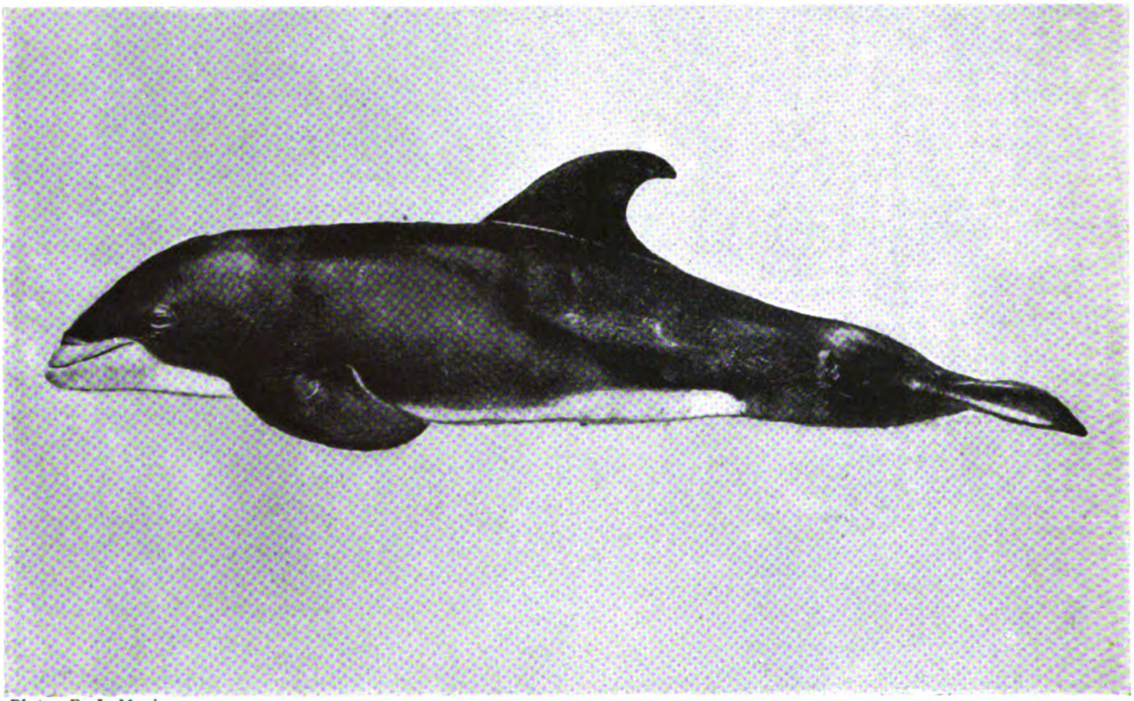


Photo: E. J. Manly.

THE WHITE-BEAKED DOLPHIN.

The name Dolphin is applied to many members of the family of whales or Cetaceans known as Delphinidæ, but it belongs in particular to the Common Dolphin (*Delphinus delphis*) abundant in the Mediterranean and elsewhere all over the seven seas. It may reach a length of seven feet. It is an intelligent open-sea mammal, with a large appetite for fish. There are 47 to 65 short sharp teeth.

so that water does not enter when the creature is submerged.

The reduction of the neck to an extreme of shortness is well-suited for diving full fathoms five and more. There are strange networks of blood vessels, which are believed by some to allow of the storing of oxygenated blood before a prolonged stay under water. There are arrangements for giving the young one a large drink of milk all at once, for suckling must be a little difficult out at sea. There is also an interesting way of shunting the larynx (at the top of the windpipe) forwards till it meets the posterior openings of the nasal passages, so that a continuous passage is formed from the external nostrils to the lungs. Therefore, when the mouth is open, in dealing with a struggling fish, for instance, the water does not go down the windpipe.

Porpoises are the commonest of British Cetaceans and many people are familiar with their gambolling in the waves. The movements are very graceful, and when a number swim together in a line with the crests of their backs showing at regular intervals above the surface, one gets a very presentable sea-serpent! Every half-minute or so, when it is hunting for food, the porpoise shows at the surface. First the snout and head are seen, then the middle of the back and the dorsal fin, finally the tail-flukes. In half a minute the snout appears again. The whole of the energy comes from the twisting thrusts of the propeller; the flippers are for balancing and sometimes for suddenly putting on a brake. Their normal position is pressed close to the sides of the body What we have just said about movements is not warm enough, for there is a delightful "go" about them when the members of a school indulge in games, as they often do. On such occasions there are often leaps and gambols, somewhat more adventurous than the ordinary rhythmic roll.

The porpoise ranges from the Mediterranean across the Atlantic, but it is commonest not very far from the coasts. It is a very familiar animal in fiords and firths like the Firth of Clyde, familiar to the ear as well as to the eye, for who does not know the sound, between a sob and a sigh, which tells one in the dusk that a porpoise has just given out a great breath of air. There is no carrying up of water in a blast as in the larger Cetaceans.

For the most part the porpoise is a fish-eater, and levies toll especially on open-sea fishes like herring and mackerel. Where the mackerel abound there are the porpoises gathered together, sometimes in schools of half a hundred. At other times they may prowl about close inshore, searching for codlings and the like, and their partiality for salmon leads them sometimes far up the rivers. They are often seen above London Bridge, and there is a record of one having been caught at Paris. The teeth are well suited for fish-catching, but they are not sharp-pointed cones as in true dolphins; they have rather spade-like crowns. They number twenty-six above and below.

With very few exceptions a single young one is born at a time, which may be in part an adaptation to the difficulty of suckling in water, and in part an indication that the security of the porpoise's tenure of life has been sufficient to allow of greatly economised multiplication—small families, in short. As is common in highly endowed mammals, there is a long period of development before birth, for the mother carries the young for about ten months before it is born. There is strong maternal affection and prolonged carefulness. In his great book on British Mammals, Millais tells of the capture of one of two porpoises that were swimming beside the boat. The captive was not killed, simply kept on board, and the other one continued swimming alongside for over half an hour. The captive was then returned to the water, and the two went off together. It is not certain that the captive was the offspring and the loyal companion the mother, but that is probable. If not, the observation illustrates a strong development of kin-sympathy.

It should be noted that the mother-porpoise, like all other Cetaceans, brings forth its young one in the open sea, in marked contrast to the seals, which have to return to the land to calve. Similarly, while the young porpoise swims right away, the young seal has to be nurtured for a

Photo: James Press Agency.

PORTUGUESE MAN-OF-WAR (Physalia).

This is an open-sea colony of modified swimming bell-like or medusoid-like individuals. Uppermost and floating on the surface is a brightly coloured bladder, like a huge inflated cock's comb. It forms a float, supporting the other members of the colony, which have nutritive, locomotor, reproductive, and other functions. It is distributed over all warm seas. Only male colonies are known. The stinging powers are virulent.

considerable time on shore. Indeed, if the very young seal tumbled into the water it would drown. The contrast indicates, of course, that porpoises and their relatives have been much longer in the sea than the seals have. This is borne out in other ways, for instance, by the absence of any external trace of hind limbs in Cetaceans, whereas in seals they are well developed though no longer of use as organs of support. Both porpoises and seals are aquatic descendants of terrestrial mammals, but the ancestors of seals were land carnivores, whereas the pedigree of the porpoise is unknown. Both illustrate the widespread tendency to seek out new kingdoms to conquer, new niches of opportunity to fill.

So far as we know, it has not been the good fortune of any naturalist to establish an intimate acquaintanceship with a porpoise, and little is certain in regard to the creature's inner life. It is a sociable, brainy, playful, affectionate animal, that has made a success of its life. It is said to have a voice, but we have never heard it.

Flotsam.

We use this convenient word for the floating things of the sea, especially for the floating living creatures. One of the momentous cleavages or partings of the ways in the realm of organisms is that between the swimmers and the drifters of the open waters. There are those that command their course—creatures of all sorts and sizes from whales to shrimps, from storm petrels to the marine insects called sea-skimmers. They are often summed up in the technical term Nekton. But on a different line of life are those that take things easily, drifting hither and thither without much effort, such as jellyfishes and Portuguese men-of-war, sea-butterflies, and the strange animals called Salps, besides enormous numbers of small fry. They are often summed up in the technical term Plankton. It must not be supposed that there are many kinds of open-sea animals that are entirely destitute of locomotor organs, though that might, perhaps, be said of some, such as the unicellular pelagic Globigerinids and Radiolarians, but there are a great many which drift much more than they swim, and these we may call *the living flotsam of the sea*. In many of the minute crustaceans the active movements have more to do with flotation than with locomotion; when they cease the little creatures sink. Without over-emphasising the line between swimmers and drifters, which is certainly not hard and fast, we may recognise that it separates two very different habits of life.

Attached to floating logs there are often great clusters of barnacles. Once they were actively swimming larvæ, but they get tired of it and fasten themselves by the front of their head. This grows out into a long elastic stalk, at the end of which the body hangs. All active locomotion has ceased, but the barnacles are very active none the less. Like their relatives the acorn-shells on the shore rocks, they are continually engaged wafting microscopic food into their mouth, sifting the water with six pairs of beautiful, biramose and plumose, curl-like limbs. Now there is a kind of barnacle (*Lepas fascicularis*) not uncommon in British waters which is distinguished from the ordinary ship-barnacle by having a very lightly built shell and a very short stalk. Its story is remarkable and a biological puzzle. When the larva abandons free-swimming it often attaches itself to a floating piece of seaweed, or to a gull's feather, or to a wooden match. It begins to grow and undergo metamorphosis in the usual way, and for a time its little float is as effective as a big log. But in the course of time the barnacle, lightly built as it is, becomes too heavy for its support, and begins to sink from the surface. This would be very disadvantageous, for it feeds on surface organisms. At this juncture what does the barnacle do but secrete a somewhat gelatinous roundish buoy containing bubbles of gas. This is secreted at the lower end of the short attaching stalk, between the extraneous float and the main body of the animal. The self-made buoy enables the barnacle to continue floating at the surface. Its "why" is plain, but we wish we understood its "how."

The case of the buoy-making barnacle is, of course, simply a striking instance of what we always find—fitness upon fitness, adaptation upon adaptation. Let us gather together a few examples of flotsam fitnesses. It is of great importance to increase floating capacity, and the meaning of a bladder filled with gas is plain. The extraordinary colony of transformed swimming-bells which we call the Portuguese men-of-war—it is a virulent stinger—is floated by means of a large reddish bladder as big as a man's hand. It

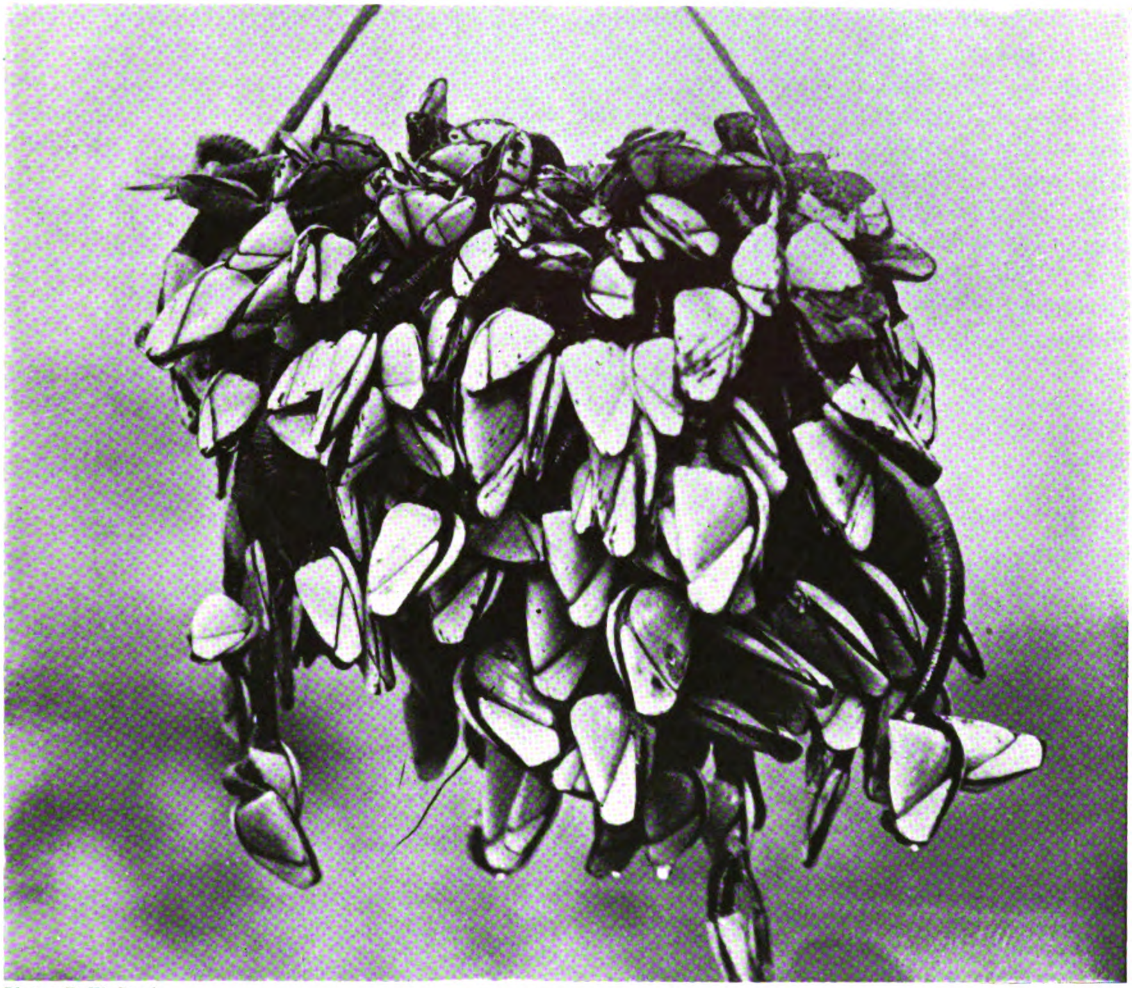


Photo: F. W. Bond.

SHIP BARNACLES (Lepas).

Barnacles are Crustaceans (Cirripeds) which are free-swimming in their larval stages, but eventually fix themselves to floating timber and the like. The front of the head grows out into a long flexible stalk, and the body becomes enclosed in five valves or shell-plates of lime. From between these there project six pairs of two-branched curled legs, which waft microscopic food into the mouth. An old idea was that Barnacles gave rise to Barnacle geese, hence the name Goose Barnacle, still occasionally used.

is a familiar sight on a voyage to the Cape ; it is conspicuous with its brightly coloured float rising above the surface like an inflated cock's-comb. Perhaps the float is also of some use as a sail, as in a dainty relative called Velella, fleets of which may be seen in the Mediterranean with their translucent blue sails rising on the surface of the water. Many of the simple unicellular animals of the flotsam have in their living matter bubbles of water of low specific gravity, and they are able to sink by bursting these bubbles ! In many of the myriads of minute crustaceans of the surface of the sea there are droplets of light oil, and many a fish egg has its flotation assisted by a large oil-globule suspended in the yolk.

Another common flotsam fitness is the growing out of long processes which make the creature almost unsinkable. Some of the extraordinarily beautiful Radiolarians have delicate outgrowths made of flint or of a glassy protein called acanthin, which give these microscopic animals a relatively large, though absolutely minute, grip of the water. What looks at first like exuberant decoration—and that aspect is undeniable—is often of use in increasing the animal's capacity for flotation. The same fitness is seen even more strikingly in many of the pinhead crustaceans (Copepods) of the open sea. The cuticle is prolonged into delicate spines, which again bear spines, so that the body comes to be supported in the water by what look like little feathers.

Many visitors to the seashore come across stranded specimens of the Angler or Fishing-frog, a grotesque fish interesting in many ways. It

has a fishing-rod on its back—a long fin-ray with a tag of skin dangling like bait on a line. It has a huge gape bordered by hinged teeth, which bend inwards, making entrance easy and exit impossible. The Angler feeds in part on other fishes whose inquisitiveness costs them their lives. But it is with the larval Anglers that we have to do, for they live in a leisurely way far out to sea. They have been recently studied by Dr. Alexander Bowman, superintendent of the scientific researches of the Fishery Board for Scotland, and they are remarkable in the possession of long streamers, like flexible ribbons, which spread out into the water in an almost incredibly extraordinary fashion. They are larval structures, and they appear to increase the flotation capacity.

In many cases, as in jellyfishes, the body is very watery, and it may be said that lightness of build is generally characteristic of the flotsam. The very common translucency is probably an expression of the delicate architecture, but one would not like to go the length of saying that it was never of value in making the creatures invisible in the water. Some of the most beautiful flotsam animals are so delicate that they cannot stand stormy weather, and their particular adaptation is to avoid the breaking waves by sinking into the calmness of deeper zones. This is finely illustrated by the sea-gooseberries or comb-bearers (Ctenophores), which are among the most beautiful animals in the sea. They are distantly related to jellyfishes, but they have the usual stinging-cells replaced by grappling adhesive cells, by means of which they capture small animals. They are intensely active, luminescent, often iridescent, carnivorous creatures, moving by means of cilia fused into little combs. But their locomotion is of a gentle sort, and we must include them in the flotsam. The point is that whenever the sea becomes the least rough—before there are any white horses to be seen—the comb-bearers descend into quietness. It is plain, then, that the living flotsam of the sea abounds in fitnesses. And, of course, a tithe has not been told.

Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

ZOOPHYTE COLONY (Campanularia) WITH POLYPS EXPANDED.

A Hydroid or Zoophyte is a fixed colony of small tubular polyps, each with a mouth and a wreath of stinging tentacles, which are well seen in the photograph. Each polyp lives in a minute bell-shaped cup, just visible to the eye. The asexual colony is formed by budding, but the Campanularians often liberate swimming-bells or medusoids which are sexual. This is called alternation of generations.

The Skate.

In contrast to an open-sea fish like the herring we wish to take one from the floor of the sea, and none could be more characteristic than the skate. Before bone develops in an individual backboned animal there is a stage with gristle or cartilage; and before any bony fishes appeared in the seas there were antique forms with skeletons of gristle. At this level skates and sharks still linger; they have no bone except in their teeth and their scales. In this respect, and in some others, skates are primitive, but while the race of fishes is represented in Ordovician rocks, dating from some hundreds of millions of years ago, it was not till Jurassic times, when birds first appeared, that there were well-defined sharks and skates.

As happened very often in the course of evolution, there was a divergence of active and sluggish types. The sharks and dogfishes became the active bullies of the upper waters; the skates and rays represent the outcome of a more sluggish mode of life on the floor of the sea.

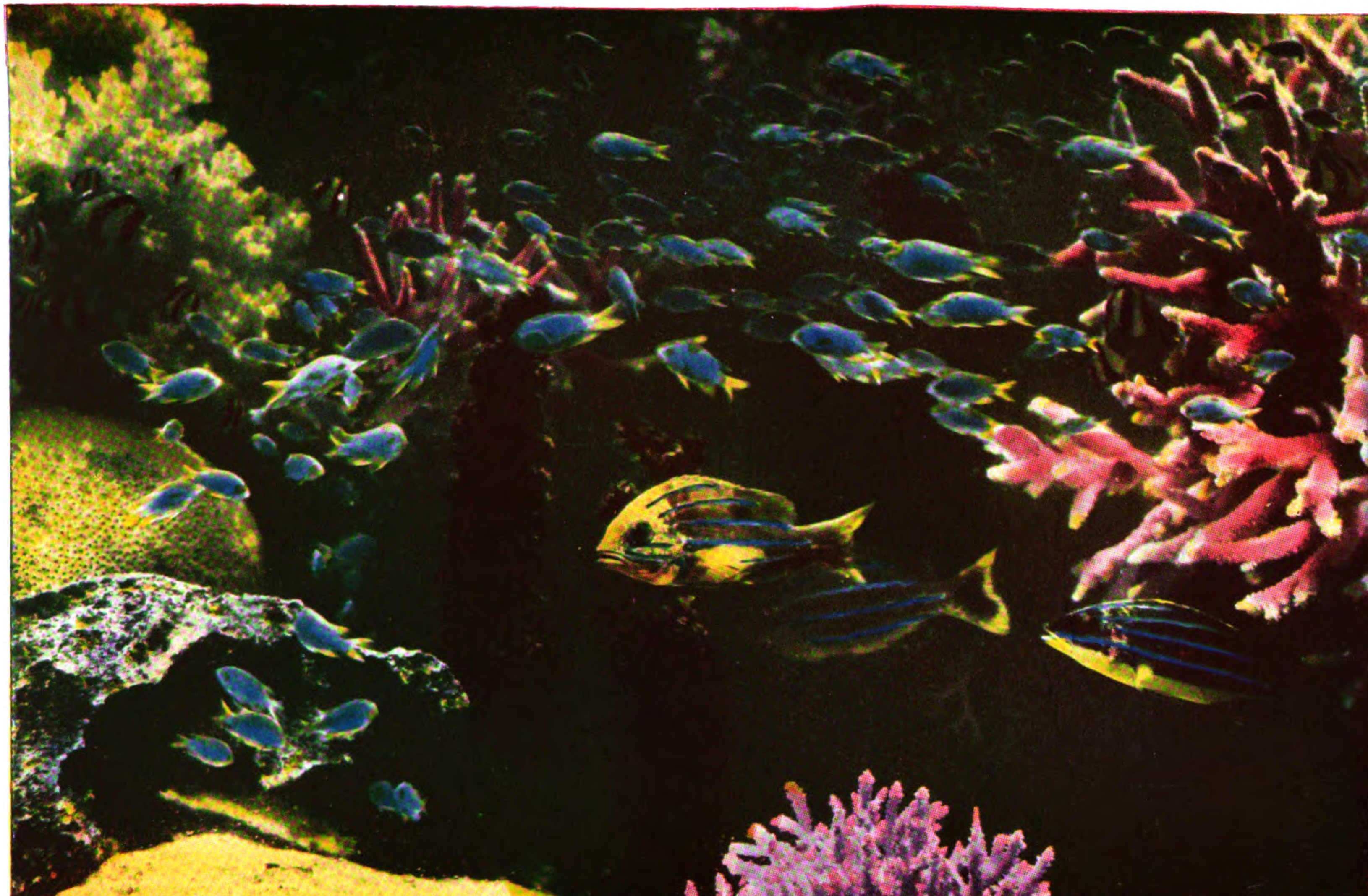


Photo: Capt. Frank Hurley.

BEAUTIFUL FISH OF A CORAL REEF.

Many of the fishes that frequent coral reefs are extraordinarily brilliant in their colouring, a common feature being the occurrence of vivid bands or stripes against a background of another colour. These bright colours are less conspicuous than one would expect, for they harmonise in some measure with the colours of the adjacent corals. But it should also be noted that it is very easy for the fishes to escape among the endless passages of the reef, and the brilliant colouration may be partly due to the fact that the animals are so safe that they can be vivid without running great risks. An interesting fact is that the same colour-patterns sometimes occur in forms that are not very nearly related to one another, e.g., in members of the families Chætodontidæ and Pomacentridæ.

There was a flattening out of the body from above downwards, and an enormous expansion of the fore-fins. A skate swims by undulating its pectoral fins, but these are mere balancing structures in a shark, which swims by lateral strokes of the posterior region. The flattening out of the skate's body brought the mouth to the ventral surface, so the creature has to get above the mollusc or crab or fish which it wishes to devour.

As locomotor functions have been shifted away from the tail region, it is not surprising to find that this has often been turned into a weapon, as in the case of the sting-rays, where it may be six feet long and carry a serrated dagger of as many inches. It will be understood that the gristly skates are not related in any way to the bony flat fishes, like halibut, plaice, and sole, which rest and swim on their left side, or like brill and turbot, which have the right side downwards. While the lie of the body is utterly different in skate and halibut, it is an interesting zoological puzzle that both types have the two eyes on the upturned surface.

True skates are usually found in relatively shallow water, where there is abundant animal life on the sea-floor. They may reach an enormous size, occasionally over six feet long, not counting the tail. They are probably protected in some measure by their sharp-pointed scales, or skin-teeth, which show a curious combination of three kinds of hard tissue. They are tipped with enamel, based in bone, and cored in ivory or dentine. In our common smooth skate or barn-door skate (*Raia batis*) the skin of the adult fish is almost without spines, but there are plenty of them on the young forms—an illustration of the usual tendency of youth to be nearer the ancestral type. Another point of evolutionary interest is the presence of an electric organ on each side of the terminal portion of a skate's tail. These seem to be structures in process of evolution, which have not advanced far enough to give a paralysing shock. They are transformations of muscle-fibres and nerve-endings, and are like initial stages of the powerful batteries possessed by electric eels and the Torpedo.

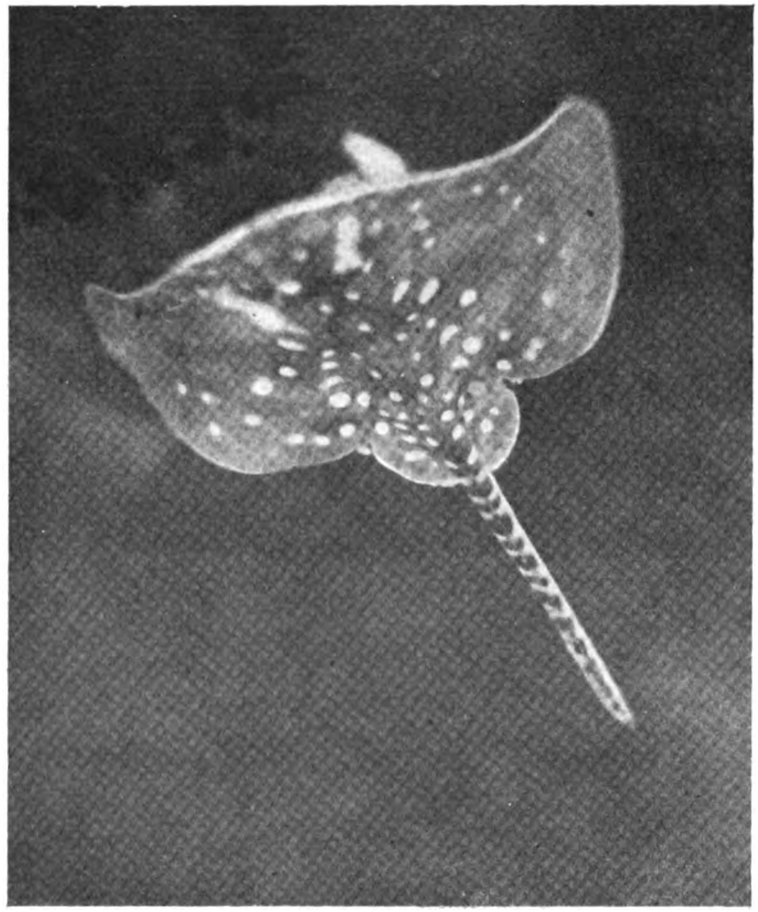


Photo: F. W. Bond.

THE SPOTTED SKATE (*Raia maculata*).

Most fishes swim by lateral strokes of the posterior body or tail, but the Skate's tail has become a weapon and is of no use as a swimming organ. The swimming devolves on the greatly expanded pectoral fins, the big triangles seen in the photograph. Behind the large pectoral fins are the small pelvics. The body of the Skate is flattened from above downwards.

Behind a skate's eyes there are two large openings into which one can thrust a finger. These are called the spiracles, and they serve for the inflow of the water used in breathing, which passes out again by five pairs of gill-clefts on the ventral surface behind the mouth. In point of fact the spiracles represent the first pair of gill-clefts turned dorsally, and by one of those

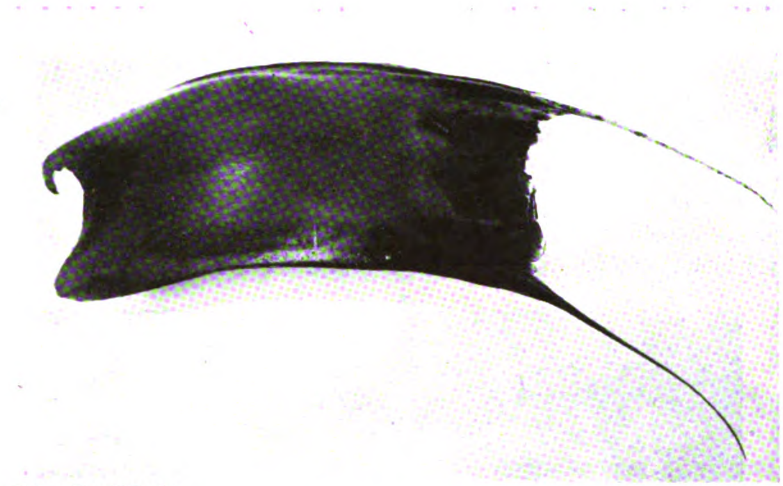


Photo: Harold Bastin.

MERMAID'S PURSE OR EGG-CASE OF SKATE.

This four-cornered egg-case is made of the same material as our finger-nails, namely, horn or keratin. It is made around the egg in the oviduct of the female fish, after the egg has been fertilised. Inside the dark-coloured horny shell, there is white of egg, or albumen, and in the middle of this the developing egg floats.

keeping up the supply of red blood corpuscles. This is of use, and the aperture is of use, but the gill itself is a mere relic.

On the under surface of a skate we see a large number of twisted jelly-tubes, embedded in the skin and ending in pin-head apertures. There are a few on the dorsal surface, especially on the head. These are sensory tubes, but it is not certain what sense they represent. Perhaps they make the fish aware of movements in the water, perhaps they are sensitive to changes of pressure, perhaps they help the fish to keep its balance in swimming. They correspond to the lateral line in bony fishes, but they remain physiological puzzles. Here it should be noted that the skate's brain is at a much higher level than that of any bony fish; and while the smelling and locomotor-control regions are particularly well developed, there is probably a glimmer of intelligence. A skate has been known to display what looked like cleverness in "trying to escape" from a trawl that was being dragged behind the vessel.

strange transformations that make comparative anatomy so fascinating, they are represented in our body by the Eustachian tubes, which establish communication between the ear passages and the back of the mouth. When we peer into a skate's spiracle we see a small comb-like structure, and this is a dwindling remnant of a gill. It is a good example of a useless vestigial organ, like an unsounded letter in a word, as Darwin said, or like one of the unusable buttons or buttonholes on a jacket. It is of no use, but it is a historical record. Hidden at its base is a peculiar cushion, which seems to help a little in

"The Mermaid's Purse" is a fanciful name for the horny shell formed round the egg of a skate or dogfish. It is a four-cornered purse, sometimes called a "shark-barrow" from its resemblance to the hand-barrow which two masons use in carrying a heavy stone. In dogfishes the purse has each corner drawn out into a long tendril which coils automatically around a frond of seaweed or a zoophyte stem, thus anchoring the egg. In skates there are no tendrils, only pointed corners, and the egg seems to be buried in the débris on the sea-floor. The size of the purse depends on

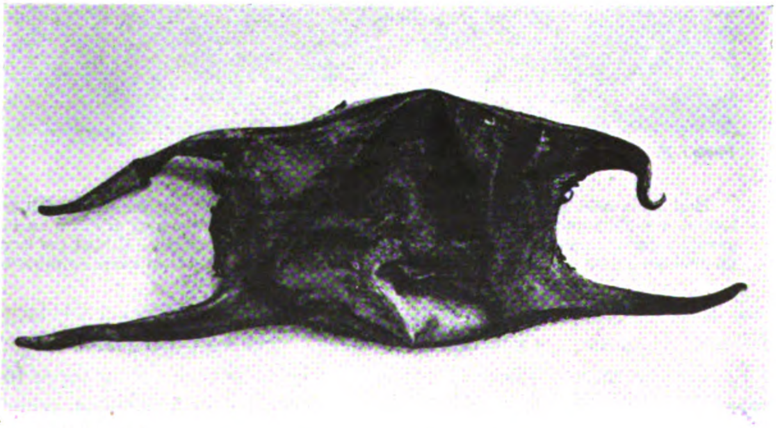


Photo: F. W. Bond.

EMPTY EGG-CASE OF THE SKATE.

The egg-case of the Skate sinks to the floor of the sea, and the egg develops very slowly. After many months a fully-formed miniature Skate may be seen lying on the top of the yolk, which is being slowly absorbed. A chemical change in the white of egg dissolves the horn at one end and out comes the little fish.

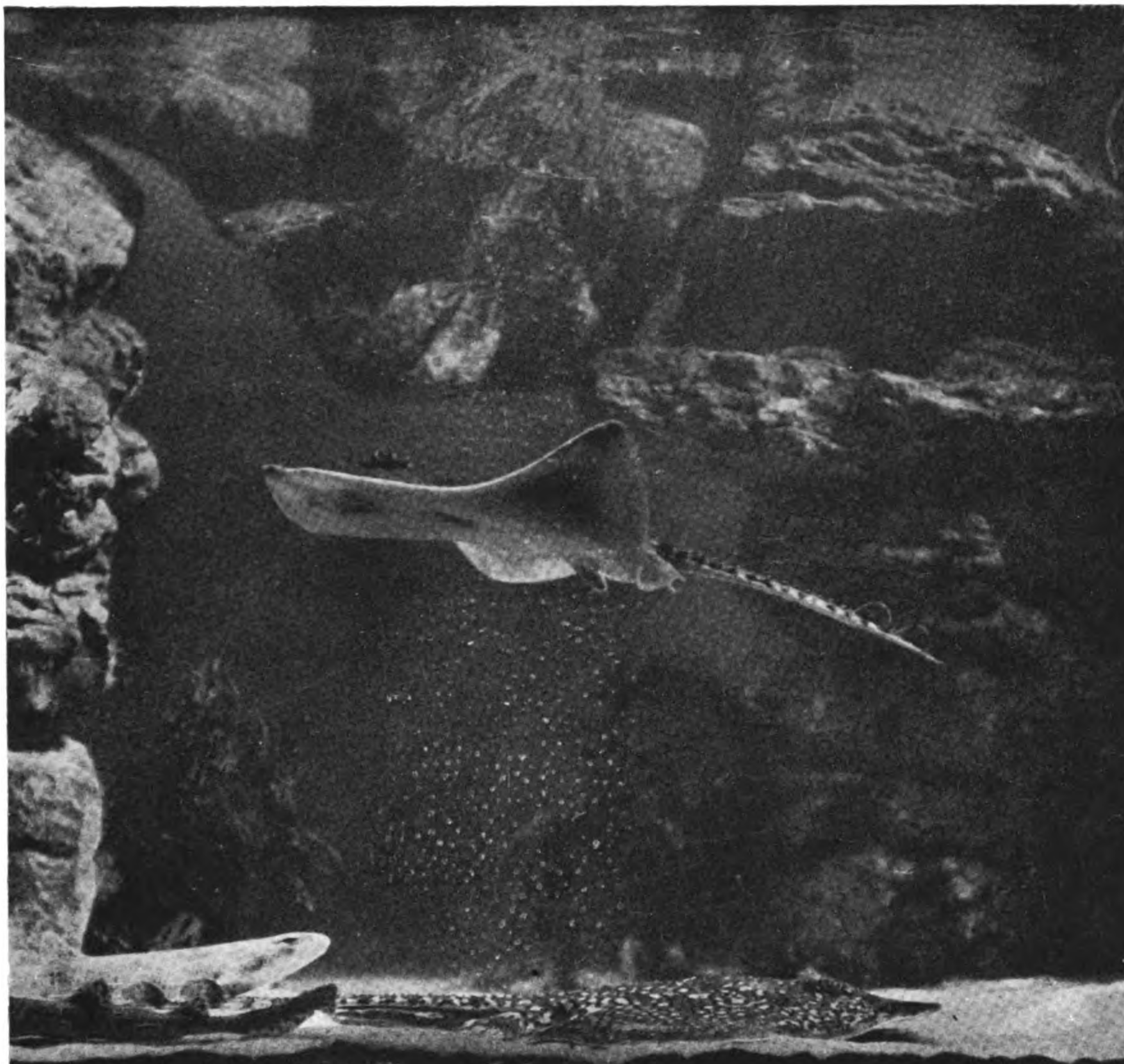


Photo: Neville Kingston.

SKATE SWIMMING.

The body of a Skate is flattened from above downwards, whereas that of a flounder, plaice, sole, or turbot is flattened from side to side. The Skate shown at the foot of this photograph is resting on its ventral surface; a plaice in the same position would be resting on its left side, a turbot on its right. In the Skate's swimming there is a wavy movement of the large triangular fin, the undulations passing from in front backwards, displacing masses of water backwards and downwards.

the species and age of the skate; we have one that is eight inches long, and this is certainly not the maximum. But a common length is about five inches.

The development of the skate's egg is very slow, taking sometimes more than six months, and thus there is the greater need for a protective egg-case. When the young skate is fully formed and has exhausted its legacy of yolk a change occurs in the white of egg, and a slit is formed by solution at one end. Through this the young skate makes its way out, but our knowledge of these matters is very scanty. The purse is made of the same material as our finger-nails (keratin), and we have seen it being formed round the egg (in an oviduct-gland) by the coalescence of multitudinous viscid threads of fluid horn. The mermaids' purses that are found among the jetsam on the seashore almost always have one end gaping, which indicates, of course, that the young skate has hatched out. To get a purse with a young skate inside is great good luck.

LXI

ISLANDS

THERE is always a fascination in islands—if they are not too large, like Australia. The charm is partly one of beauty, for many a small island is a fine picture in itself, and then there is the glistening frame of sea. There is also a feeling of unity in the sea-girt isle that one cannot have on a continent. Even when the island is a small one—a mere islet in a river or lake, a ridge of rock rising in the sea—it excites expectancy, a hope of discovery, unless, indeed, it be so familiar that we have ceased to think about it at all. Every island may be a Treasure Island. Who has been here before us? Is there a Robinson Crusoe on the island, or even an otter that has ventured far from shore? What jetsam may we find on the beach, what secrets in the caves and hidden places, what view will reward us when we climb to the summit? And again, around a well-known island there cling historical associations, unextinguishable lights from the past—from Patmos to Atlantis, from Corsica to St. Helena, from Bermuda to Tobago.

But we doubt if the scientific fascination is not greatest of all. How did the island begin; what has been its history; how has it been peopled by plants, by animals, and by men; what has

Photo: L. E. A.

ISLANDS IN THE MAKING.

On many parts of our coast stacks of rock become isolated by the breaking down of the bridge which originally connected them with the land. What was for a long time a carved-out cape becomes an island, a very safe place for nesting birds.

Photo: Chas. Barrett.

BEACH OF A QUEENSLAND CORAL ISLAND.

Whether a coral island rises on the shoulders of a volcano which did not reach the surface, or is formed around an island which was slowly submerged, or arises in some other way, it is always built up of colonies of reef-corals, and of the fragments which are formed as the result of their breakage and weathering. To the inside of the reef which grows outwards into the sea, there is often a stretch of fine sand. This may be used, as in the island photographed above, by the Green or Edible Turtle (*Chelone mydas*) as a suitable place in which to lay the parchment-shelled eggs.

happened in the course of long isolation? To those who feel the charm of islands we would recommend a very delightful book, to which we acknowledge indebtedness, Mr. Hyatt Verrill's "Islands and their Mysteries" (1923).

Of islands there are two great kinds—the continental and the oceanic. A continental island was once part of the nearest continent; but "nearest" is a relative term, as we see in contrasting Great Britain, a continental island separated from Europe, with New Zealand, a continental island separated from Australia. The detachment of an island from the mainland may be brought about by a subsidence of part of the continent, or, in the case of small islands, by an erosion severe enough to break through a peninsula. On many coasts we can see the island-making going on, when rocky prominences are gradually separated off from the shore, and become isolated stacks. Continental islands, whether large or small, are often called *destructional* by the geologists. That is to say, they arise by some destruction of dry land—the submergence or breaking down of a natural land bridge. They are, so to speak, *on the minus side.*

Continental Islands.

While continental islands are pieces of land stolen from the main masses, oceanic islands are positive gains rather than losses. They are made by the tops of submarine volcanoes, or by the peaks of a slowly rising mountain chain, or by coral growths on the shoulders of either of these. As an oceanic island was not previously part of something else, it is sometimes called *constructional*, being, so to speak, on the *plus* side. It has been suggested by some geologists that the gradual elevation of a submarine plateau may lead to the formation of an archipelago of islands, and that continued elevation may result in a continental mass. If this be true, islands may give rise by their coalescence to continents; but what is much more evident is that continents may give rise to islands, as Africa to Madagascar.

Oceanic Islands.

Although the starting-point of a coral island is a volcanic peak, or a worn-down oceanic island, or the shelf of shallow water round a coast, their way of growing puts coral islands by

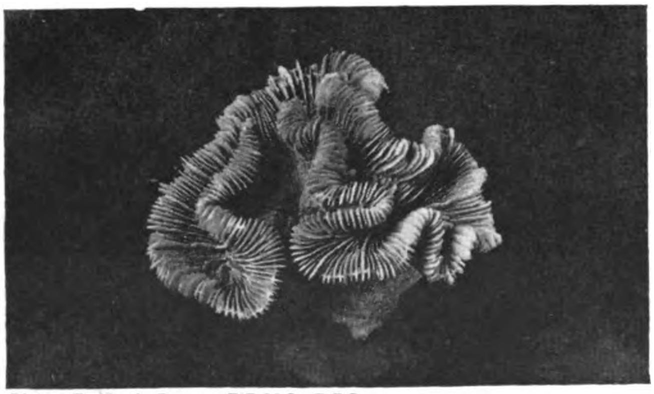


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

A FOLIACEOUS CORAL.

The Foliaceous Corals, found in tropic seas, grow to a large size, a single colony often resembling a huge cabbage. The component polyps are light brown in colour.

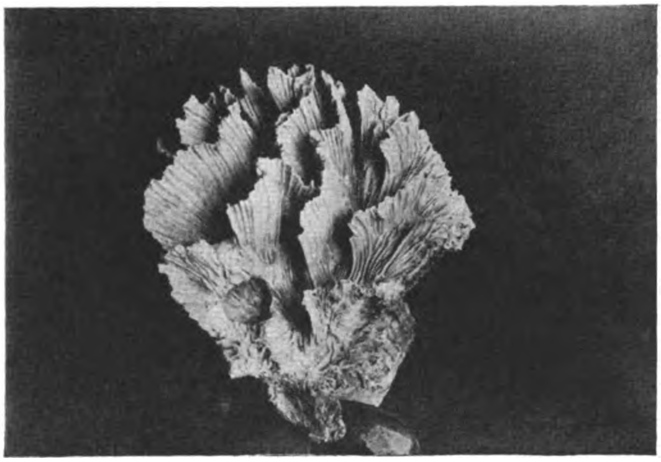


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

A REEF-CORAL.

One of the many reef-building corals, a colony consisting of a large number of individual polyps which multiply in situ by budding or by division.

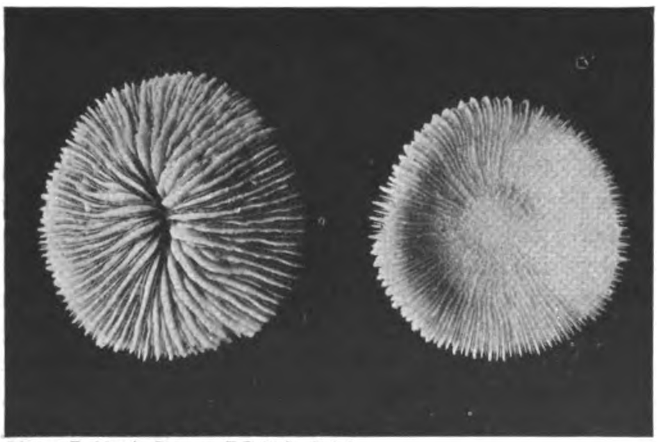


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

MUSHROOM CORALS, SHOWING UPPER AND UNDER SURFACE.

This is the cup or skeleton of a single individual or polyp which resembled in many ways a large sea-anemone.

themselves. For, as everyone knows, they are due to the shells or skeletons of lime formed from the salts of the sea by vast colonies of coral-polyps, related to sea-anemones. Reef-building corals require a warm and shallow sea, with abundance of food and much movement, away from inflowing freshwater and away from land-sediment. Those coral atolls that occur far from land, with deep water all round them, are there only because a submarine volcano top has been raised near the surface—near enough to give anchorage to the free-swimming young stages of corals. Or it might be that corals establish themselves on some lost oceanic island that has been worn down below the surface of the sea. In any case, no reef-building corals can thrive at a depth exceeding thirty fathoms, and most of them prefer five to seven.

Coral Islands.

We have spoken of all islands—not too large—as fascinating, but the palm must be given to islands made of coral. Their peculiar charm is partly because they are often circles or semi-circles, partly because the coral-animals disclosed at low tide are beautifully coloured and build up beautiful constructions of lime. But perhaps part of the charm lies in our knowledge of the fact that these great circles and half-circles and fringing reefs have been built up by the activity of colonies of coral polyps which have absorbed from the sea the stones and mortar of their beautiful edifices. There are hundreds and hundreds of coral islands, especially in the Pacific and Indian Oceans, and they mean, when taken together, a big addition to the solid above-water earth of the globe. Many of them bear palm-trees and a variety of plants; some of them are inhabited by man; all of them have lots of animals creeping about or swimming about in the mazes of coral-growth. Coral-polyps

have been the greatest builders in the world; and the largest fact that we must be clear about is this, that they take the lime-salts dissolved in the seawater, and build them up into substantial shells or skeletons of carbonate of lime. Thus, they recapture in fixed form the lime-salts which the rivers had filched from the dry land.

It is still common to talk about coral-*insects*, but that is a very unfortunate name. The coral animals or polyps that make coral reefs are all nearly related to the soft sea-anemones that we see nestling in the niches of the shore-rocks. Each individual surrounds itself with a cup or shell, and as they multiply by budding and by dividing, they form great colonies. These are often so compacted together that it is difficult to tell where one polyp ends and its neighbour begins. As new individuals are added to the surface of the colony, the older members gradually die away, or are smothered. The new generations live very literally on the shoulders of their predecessors, and if we break open a large lump of reef-coral we find that the lower and inner parts have already turned into solid rock.

A coral-reef growing out from the shore and connected with the beach by a shallow lagoon, often drained at low tide, is called a *fringing reef*. When the waves break off great pieces along the outer margin, some of these are hurled inwards and some tumble down the outer slope. As those on the outer slope accumulate, they form a foundation for further growth seawards. When this extends to a considerable distance—even many miles from the land—it results in a *barrier reef*. The tearing off of coral-blocks is very important both in the seaward growth of foundations and in piling up of rock that rises above the surface.

On his voyage in the *Beagle*—one of the most important of all voyages, for

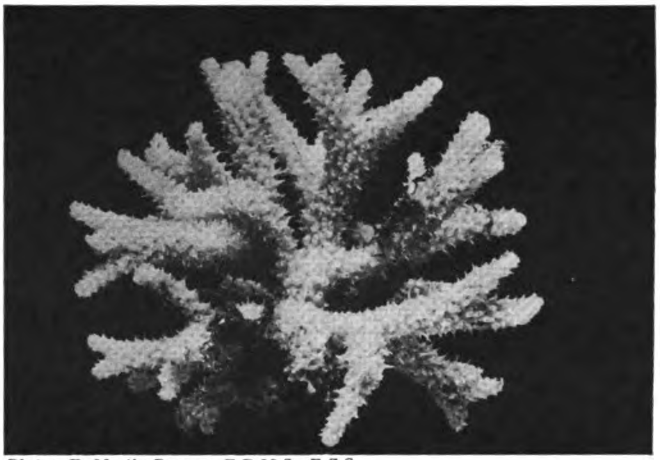


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

"LACE CORALS" (Cellepora).

This is a colony of Moss-animals or Bryozoa, far removed from true corals, but with a strong calcareous investment for the component individuals.

Photo: W. S. Berridge, F.Z.S.

CORAL (*Turbinaria conspicua*).

A true Madrepore coral-colony, that grows in a twisted leaf-like fashion. A specimen in the British Museum is 16 feet in circumference.

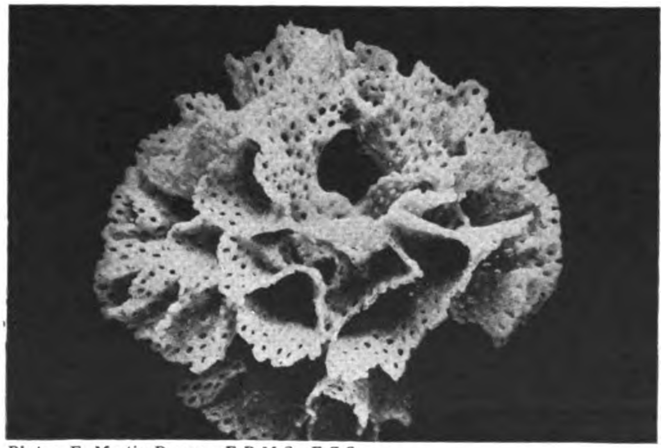


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

NET CORALS (Retepora).

This is another of the beautiful Moss-animals or Bryozoa, nearer "worms" than polyps. The dark spots are holes in the net-like colony.

it discovered a new world, *an evolving world* — Charles Darwin became greatly interested in coral-reefs. "Everyone," he writes, "must be struck with astonishment when he first beholds one of these vast rings of coral-rock, often many leagues in diameter, here and there surmounted by a low verdant island with dazzling white shores, bathed on the outside by the foaming breakers of the ocean, and on the inside surrounding a calm expanse of water, which, from reflection, is generally of a bright but pale green colour."

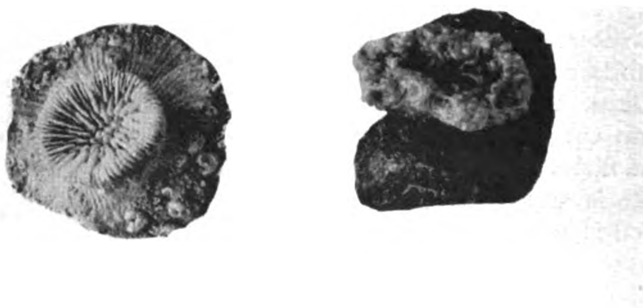


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

DEVONSHIRE CUP CORAL (Caryophyllia).

This simple British Coral, here shown in natural size, is a single individual, like a sea-anemone, with the base of the skeleton fastened to rock or stone, or shell.

In his picture of the making of coral islands, Darwin started with an island surrounded by a fringing reef, and supposed that the sea-floor began slowly to sink. This would reduce the size of the island, and would increase the distance between the land and the growing outer margin of the reef. The result would be a barrier reef. As the slow sinking continued, the island would disappear, leaving an irregular ring of rock round a shallow lagoon. Thus would arise a typical coral island or atoll. The gist of the theory is that fringing reef, barrier reef, and atoll represent three successive stages, and that the passage from one to another is connected with slow subsidence of the sea-floor.

One of the difficulties in accepting Darwin's picture as the whole story is that while some coral reefs have arisen in areas where the floor of the sea has slowly subsided, others have arisen in areas of uplift. The great borings undertaken at Funafuti showed coral rock at a depth of 1,114 feet below sea level, pointing to

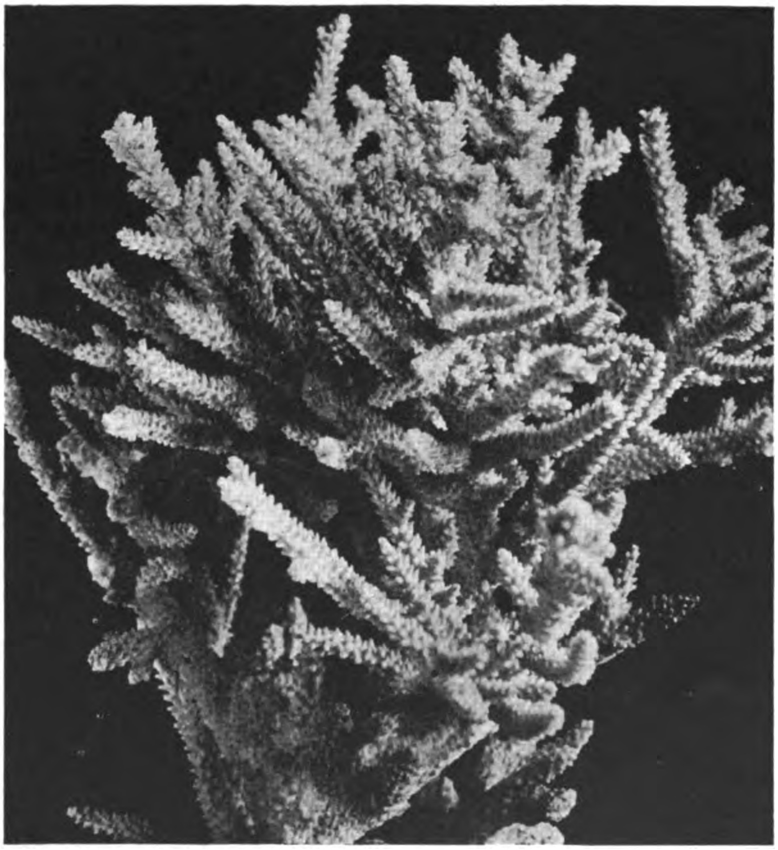


Photo: H. J. Shepstone.

AN INDIAN OCEAN CORAL.

This is an elegant colony with numerous small calices disposed all round the finger-like branches. Each calyx is the shell or cup of a sea-anemone-like polyp, and the colony grows by budding till there are thousands of component individuals.

Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

STAR CORAL.

This is the beautiful skeleton of one of the Star-corals or Astræidæ, in which the boundaries of the individuals that make up the colony are for the most part clearly defined, not coalescing as they do in the Brain-corals. The colony is formed by a process of budding often repeated.

coral. The circular shape of the atoll tends to arise, according to Sir John Murray, because the growth of the coral is always most vigorous to the exposed outer side, and because the less vigorous, or dead, coral to the inner side is dissolved away, thus giving origin automatically to a shallow lagoon.

If volcanic activity formed a peak which did not reach the level of thirty fathoms below the surface, or if unusually deep erosion should wear down a former island to a depth too great for coral growth, it is possible, as Sir John Murray pointed out, that in the course of ages the platform might be raised to the required level by the slow deposition and consolidation of minute calcareous animals, such as Foraminifera, sinking down from the surface. Thick beds of chalk have been formed in this

long-continued subsidence; but in the Fiji group there are raised coral reefs a thousand feet above the sea, and that is by no means the maximum of uplift.

During another great "Columbus voyage," the *Challenger* Expedition, which practically discovered the new world of the Deep Sea, Sir John Murray thought out another theory of coral reefs. He started from a volcanic peak that did not reach the surface, or from an island that had been worn down by wave-action. This wave-action ceases at a depth of about thirty fathoms—the level at which corals begin to grow. A few actual cases are known where a volcanic island of small size has been worn down to a hidden bank which has then become a platform for the growth of

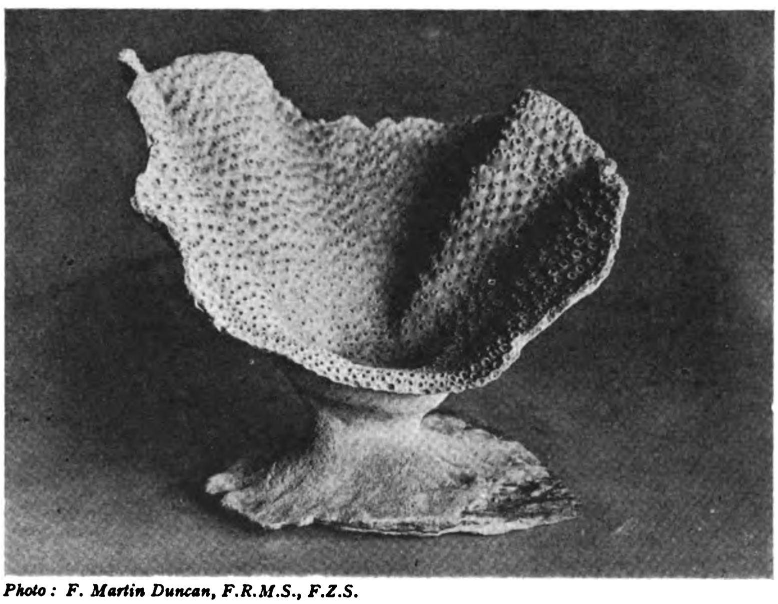


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

NEPTUNE'S CUP CORAL.

Although this has a cup-like form it is not near the simple Cup corals, like the British Caryophyllia. For this is a colony of very numerous individuals, whose projecting calices are very clearly shown in the interior of the cup, which has been partly broken.

way on the floor of ancient seas, and it may be that this process has sometimes played its part in laying the foundations for a coral island.

It is interesting to picture a submarine volcano-top being slowly raised by the rainfall of exquisite microscopic minutiæ which become cemented together to form the strongest foundation in the world. The platform slowly rises century after century, millennium after millennium, till it reaches a level at which the free-swimming young stages of corals find it a suitable anchorage. They settle down and begin to form their castles of indolence. They multiply and spread, without haste, without rest; they are battered and broken, and the dislodged pieces extend the foundations outwards or are piled up to the inner side. There is a smothering of the living by dislodged pieces of dead coral-rock, and on the shoulders of the dead a new life extends. At last a ring of rock emerges from the sea—the coral island is made.

Photo: M. H. Crawford.

SEA-MAT (*Flustra foliacea*).

The Sea-mat is a somewhat seaweed-like brown colony of small animals belonging to the class of Polyzoa or Bryozoa. Many members of this class are very calcareous and may thus be called "corals," but the Sea-mat has a flexible "horny" skeleton. The first scientific paper that Charles Darwin wrote was on the Sea-mat.

Professor James Park, of Otago, has called attention to the alternations of waste and repair on the growing reef. During the cyclonic storms the outer edge is broken into small fragments and large blocks; these are piled pell-mell on the top of the living coral; the water becomes thick with coral-mud, but this is dissolved before it does much in the way of smothering. "The spreading umbrellas are broken, and jagged masses of coral lie everywhere. The wreck of the reef seems beyond repair. But in a few days the water clears, and almost at once the coral-builders begin the work of reconstruction. The old polyps are rejuvenated, and fresh larvæ start new colonies." This alternation of demolition and reconstruction must be added to our picture. The coral-city is always being broken down and rebuilt.

Of course it must be understood that besides the sea-anemone-like coral polyps there are other living creatures that share in making the coral island. There are calcareous seaweeds that look very unlike plants and might well be called "plant-corals"; there are multitudes of chalk-forming unicellular animals, the Foraminifera; and an important part is sometimes played by molluscs and by tube-inhabiting worms. The coral reef is a submarine thicket for many kinds of animals and there is often a bustle of life in the part exposed at low tide.

Recent studies of coral reefs point to the conclusion that they may grow on a stationary, a sinking, or a rising sea-floor. A fringing reef may become a barrier reef, as Darwin said, but a barrier reef may also become a fringing reef. When there is a sinking of the sea-floor the result will depend on whether the rate of sinking is less than or equal to the rate of coral growth. If the rate of sinking be *greater* than the rate of coral growth, the reef will be submerged below the limit of coral life, but when the subsidence stops

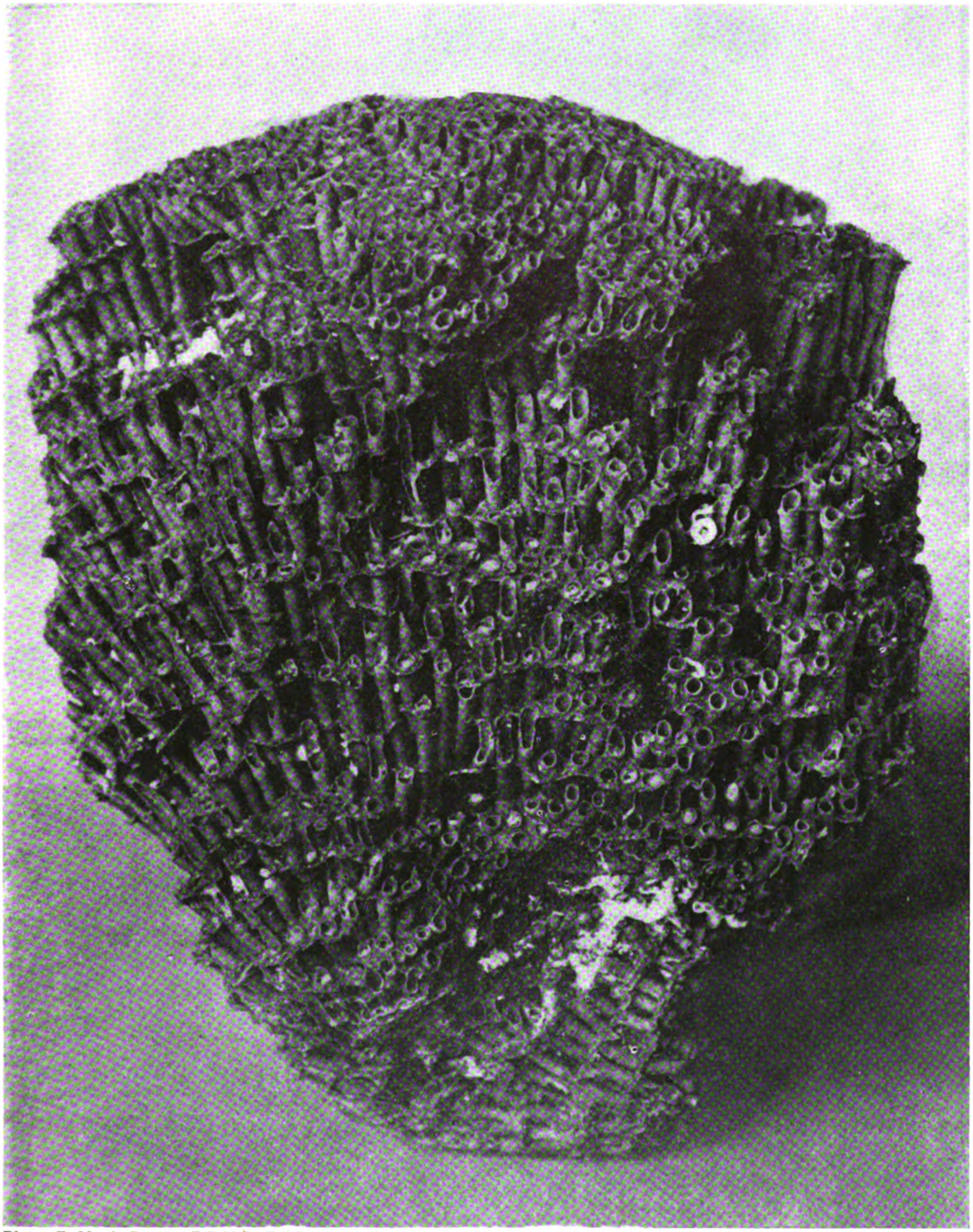


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

ORGAN-PIPE CORAL (*Tubipora musica*).

This is a natural size photograph of the Organ-pipe Coral, one of the Alcyonarians. Each polyp lives in a red tube, composed of fused spicules of lime. These are often threaded together to make necklaces for children. The numerous pipes are bound crosswise by bridges and in each pipe is a soft polyp which can protrude eight green feathered tentacles at the top. Tubipora is very common in shallow water at the edge of the coral reefs of the Old World and the New. But it is not strong enough to be a reef-builder.

Photo : Neville Kingston.

A LIVING ALCYONARIAN CORAL.

This beautiful colony, branching like a shrub, is one of the Alcyonarian "corals," a class including sea-fans, sea-pens, and "Dead Men's Fingers." There are many hundreds of polyps, all united by canals in a common life. Each has eight feathered tentacles, and each is armoured with spicules of lime, which often contribute to a central axis that usually supports the whole.

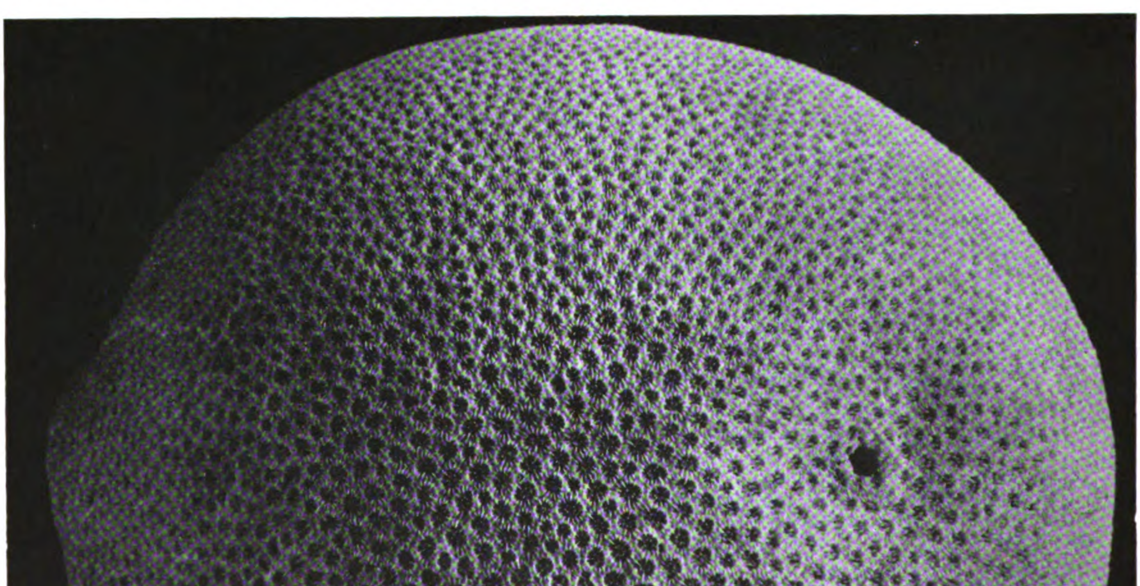


Photo : H. J. Shepstone.

INDIAN OCEAN CORAL.

The word "coral" is applied to hundreds of different animals, and it must be understood that there is no class of corals. There are Hydroid "corals" related to the Hydroid zoophytes, like the sea-firs ; there are Madrepore "corals" related to sea-anemones ; there are Black "corals" with stems like ebony ; there are Alcyonarian "corals" like the sea-fans ; there are Bryozoan "corals" related to the sea-mat ; and there are more besides.

the platform of reef may be raised again by the accumulation of the Foraminifera and the like sinking down from the surface. If the sea-floor is stationary an atoll may be formed, as Sir John Murray showed, without passing through the fringing reef and barrier reef stages. In short, it is possible to combine the two chief theories—Darwin's and Murray's.

To our story of coral islands we wish to add a short account of corals in general. Judged in

Corals.

regard to their beauty, corals rank high, but, for animals, they have not many habits. It is difficult to believe that they are quite awake; they seem to be dreaming, and their beauty corresponds to the smiles of a child asleep. There always seems a contradiction in terms in *sedentary* animals; it is a surrender of the birthright of locomotion, though they usually insist on asserting this in their earliest stages. Yet no one can say that corals have lost any beauty in becoming fixed. In their architecture, and even in the stones or spicules with which many of them build, they are exquisitely beautiful, and the same is often true of their colouring when alive, and of the branching of those that form colonies.

We recently obtained for identification a sea-anemone-like solitary cup-coral, which the *Michael Sars* Expedition had dredged from a depth of about three miles in the North Atlantic. We boiled away the brownish flesh and disclosed what angels might desire to look into. It is not much bigger than an egg cup, but it is like a king's crown dimpled in. Pure glistening white, it might be a rose-bowl for the Queen of the Fairies. We keep it in a jewel-box and look at it on feast-days. We refuse to think of the time when it must go back to Norway with a label. There is no doing justice to the beauty of these things, and there are scores of them, born to blush unseen in the deep sea. They are superlatively beautiful, that is all one can say. They are organic dream-smiles.

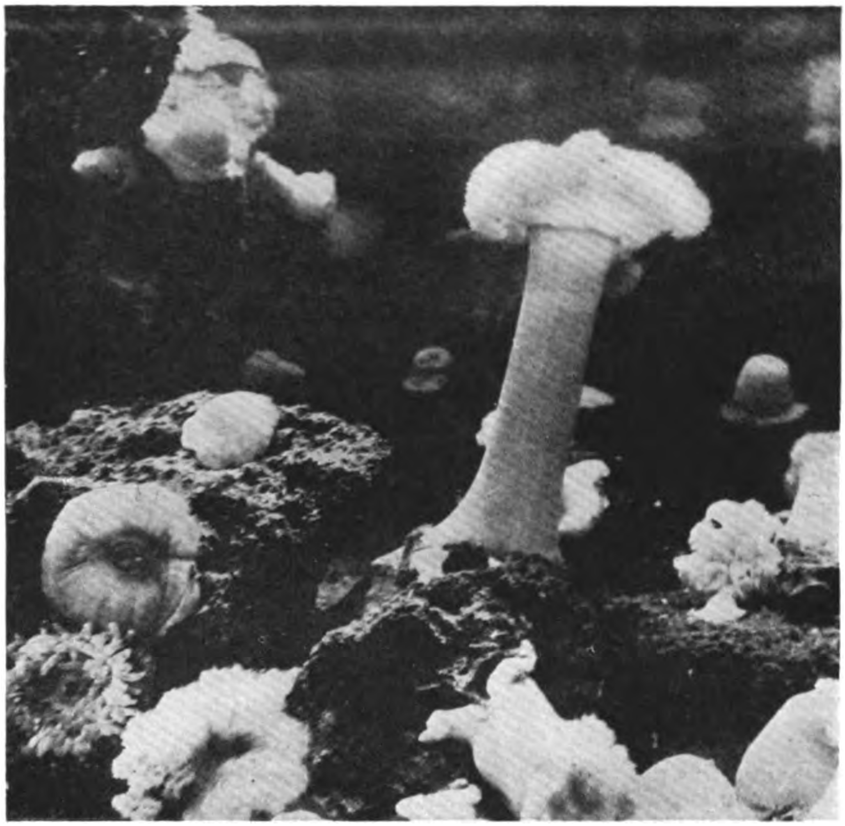


Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

SEA-ANEMONES ON THE ROCKS.

There is a suggestion of a cluster of flowers in a group of sea-anemones, partly because of the radial symmetry like that of chrysanthemums, partly because of the fine colouring. The cylindrical body is fixed by its base, and the mouth at the upper pole is surrounded by whorls of stinging tentacles which are usually retractile. The most prominent sea-anemone in the photograph is the Plumose Anemone, *Actinoloba dianthus*, which has a frilled or puckered disc, bearing numerous small tentacles.

There is no class or group of "corals," for the word is simply a convenient name for those kinds of stinging animals (or Cœlentera) that form very hard, substantial skeletons, usually of carbonate of lime. Perhaps it may be useful to take a survey of "corals." See Prof. S. J. Hickson's fine book on "Corals" (1925).

Sea-anemones, as everyone knows, are soft-bodied, cylindrical animals with stinging tentacles encircling the mouth and with a basal disc

Photo: Reproduced from "Pearls and Savages," Capt. Frank Hurley, by courtesy of the publishers, Messrs. G. P. Putnam's Sons.

A CORAL REEF OFF DAUKO ISLAND.

The coral reefs cover a vast area off the Queensland coast. To quote Capt. Hurley, "The range of colour baffles description and resembles a vast flower garden." There are delicate pink corals, so frail as to break at the slightest touch, and more sturdy corals scarcely to be chipped with a hammer.

usually attached to a rock. Nearly related to these sea-anemones are the solitary cup-corals, where the skin of the animal forms a shell of lime. For the word "shell" is at least as appropriate as the word "skeleton." As the wall of the cup is gradually added to and rises, the skin of the animal may fold over it, and internal partitions of lime are formed, radiating from the wall of the cup to the centre, where they sometimes unite in a pillar. But as the partitions or septa rise, pushing their way, as it were, into the body of the coral-polyp, the fleshy tissues retreat before them, so that, in spite of appearances, the coral skeleton is always *external* to the living animal. Our own skeleton is obviously inside our muscles, and it is alive; the cup-coral's skeleton is outside, though it may not seem so, and it is quite devoid of life. It is added to, but it does not grow. The cells that contribute the stones and mortar to the coral edifice die in so doing. No doubt the lime comes from the sea-water, but carbonate of lime is a scarce salt in solution in the sea as compared with calcium sulphate, and there is much to be said for the theory that ammonium-carbonate, formed as a waste product in the marine animal, undergoes "double decomposition" with calcium sulphate from the sea-water, yielding ammonium sulphate which passes out in solution, and calcium carbonate which forms the coral's "castle of indolence."

From a solitary cup-coral there is a gradual transition to the reef-building corals or Madrepores, which are great colonies of individuals. They arise by the budding and division of polyps, and the crowding often becomes so intense that individuals merge. Thus in a big block of brain-coral, so-called from its suggestion of the convolutions of a mammal's brain, it is impossible to tell on the cleaned skeleton where one individual ended and another began. When the coral is living one can, of course, distinguish

and count the individual mouths with their wreaths of tentacles. Such a colonial coral is sometimes beautifully arborescent, so that individuals of many different ages may be flourishing together ; but in most cases the new generations grow on the shoulders of the old and smother them. Thus the greater part of a coral colony is a cemetery. By filching lime from the sea these reef-building Madrepore corals have added greatly to the solid earth. The Great Barrier Reef of Australia stretches for over a thousand miles !

Next to the Madrepore corals, but utterly unlike them, are the black corals or Antipatharians. They are most abundant in the warmer seas, but British trawlers bring in large colonies from northern waters, such as off the Faroe Islands. We sympathise with the fishermen in their protest that their captures are plants, for some of them are like dwarfed Japanese trees, and others suggest the stems of some climbing plant like honeysuckle. But close scrutiny shows a crowded multitude of small polyps, usually with six simple tentacles, and forming in their midst a black horny axis covered with prickles like a branch of briar. In old colonies this axis may be thicker than one's thumb and as hard and black as ebony. It takes on a beautiful polish, but it is hard stuff to carve.

If one suddenly says " coral " to a lady, she thinks at once of beads or babies, whereas a man thinks of coral islands and either of Ballantyne or of Darwin, according to his upbringing. The beads and the baby's amulets are carved from the axis of the Precious Coral, *Corallium rubrum*, which is fished in Mediterranean and in Japanese waters. It has white polyps embedded in red flesh, and in the centre there is the coral-red axis, always being added to in some mysterious way, perhaps implying a rapid solution of the lime, followed by an equally rapid hardening. The red flesh connecting the polyps by an intricate system of canals owes its redness to the presence of innumerable red spicules of microscopic size and rather ornate shape. Now it is from some kind of coalescence of these quite separate spicules that the solid central axis is formed. There is the same difficulty in the case of the Organ Pipe

Photo: Reproduced from " Islands and their Mysteries," A. Hyatt Verrill, by courtesy of the publishers, Messrs. Andrew Melrose, Ltd.

A VOLCANIC ISLAND.

There are two great kinds of islands, (*a*) continental islands, which are separated off pieces of the mainland ; and (*b*) oceanic islands, which usually arise as the result of a submarine volcanic eruption. The photograph shows an oceanic island.

Photo: By courtesy of the Natural History Museum, South Kensington.

ROBBER CRABS.

This Land-crab is often over a foot in length. It frequents coral islands in the Indian and Pacific Oceans, where coco-nut palm-trees have been introduced. It often climbs the trees to get the nuts. The shell is broken by hammering with the great claw on the "eye-hole"; the pulp is eaten; the husk is used to line the burrow; the shell is sometimes carried about to protect the abdomen.

Coral, ***Tubipora musica,*** whose finely coloured tubelets are threaded into necklaces for children. Each polyp, mostly white in colour, lives in a red tube of lime, and the scores of tubes are subtly bound together like "a kist o' whistles." On the polyp, where it puts its head out, we can just see little rings of separate red spicules. In a short time a group of these will be added on to the upper rim of the hard tube, but how it is done we do not know. We fancy that there must be a rapid solution and then a rapid reprecipitation in another form. Corals like the "Precious" and the "Organ Pipe" are called Alcyonarians, and are near relatives of Sea-fans and Sea-pens and Dead Men's Fingers, as also of the rare Blue Coral (Heliopora), which is the only living representative of an extinct race of great antiquity. And here we may mention that of the ancient Rugose Corals that are exceedingly common as fossils there are no living representatives at all. One race cometh and another goeth. All things flow, as Heraclitus said, even corals.

This survey has its use in showing that the word "coral" is a physiological term, indicating a habit of life, for we have seen that it includes, among living types the Madrepores, the Antipatharians, and the Alcyonarians, which are not nearly related to one another. Coral means a sedentary Stinging Animal, given to making a hard skeleton, usually of lime. To those we have mentioned must be added two other orders, the Millepores and the Stylasterids. These belong to a different class altogether—the Hydroid zoophytes—and it must be interesting to see a minute swimming-bell or medusoid issuing forth from a stony Millepore, for there is alternation of generations here just as in many of our common zoophytes. But this is certainly another story.

Floating Islands.

There are a few kinds of islands which must be kept by themselves—being neither continental, oceanic, or coral. Thus, at the mouths of great rivers, or in their course, there are sometimes huge deposits of mud and sand and gravel which get piled up above the water-level and become covered with vegetation. Or a river may form an island by a shifting of its course, and we often

see this on a small scale when a flood finds a short-cut between two bends of a winding stream.

There are strange "floating islands," sometimes small, like the one that appears periodically in Derwentwater, but sometimes large enough to carry a village. They seem to arise in various ways, for instance by the accumulation of enormous masses of dead brushwood and the like at the mouth of a river; or by the growth of crowded tangles of vegetation on the surface, and the addition of sheets of dead débris raised from the bottom by the evolution of marsh gas in hot weather. Oftenest, perhaps, floating islands are separated-off masses of shore vegetation which have grown out among mangrove roots, osiers, bulrushes and reeds, and caught up a certain amount of soil during floods or high tides. In the course of time the complicated masses of vegetation become compact and coherent, and substantial enough to bear trees of their own! In a storm they are sometimes broken loose like rafts from their moorings, and then they are not merely floating, but *drifting* islands.

In his "Voyage of the Beagle" Darwin tells us of the floating islands of Lake Tatuatagua in Chile. "They are composed of various dead plants intertwined together, and on the surface of which other living ones take root. Their form is generally circular, and their thickness from four to six feet, of which the greater part is immersed in the water. As the wind blows they pass from one side of the lake to the other, and often carry cattle and horses as passengers." It is strange to think of an island serving as a ferry-boat!

There are islands of salt and islands of ice, but one of the strangest of all is Saba, in Caribbean waters. Mr. Hyatt Verrill gives us a vivid picture of its Dutch village, called Bottom, which nestles in the crater of a sleeping volcano, a thousand feet or more above the sea. The chief industry is boat-building! "When the boat is built, they lower it over the edge of the cliff with block and tackle, exactly as though the island were a ship and they were lowering a lifeboat."

When we think of the plants and animals found on islands, three big questions rise. The first is: *Where they came from?* and this brings out the striking difference between continental and oceanic islands. For a continental island will have, to start with, a fair sample of the fauna and flora of the land-mass from which it was

Natural History Questions.

Photo: Chas. Barrett.

COCO-PALMS (*Cocos nucifera*).

This well-known palm flourishes well near the sea, and its big nuts can be drifted far without injury. Thus the Coco-Palm has been for a long time very widely distributed. It furnishes the necessities of life, and some of the luxuries, to the inhabitants of many tropical countries. Perhaps there is no other plant that is of use in such a variety of ways.

separated off ; whereas an oceanic island must be restricted to those plants and animals that could be carried thither by currents and winds and on the feet of birds, or, in the case of some animals, could actively reach the island by swimming or by flight. On Christmas Island—the one in the Pacific—there are Coco-Nut palms which the Robber-crabs climb, but wherever these palms came from, they are certainly not native to the island. The nuts must have drifted from distant coasts, and the same thing must have happened over and over again, for palms occur on many of these oceanic islands.

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TREES ON A FLOATING ISLAND.

A floating island may be formed in various ways, for instance, by the flooding-off of a great accumulation of brushwood brought down by a river and deposited in the slow-flowing estuarine region. In the course of years there may be a growth of plants and the capturing of some soil in flood time. Even trees may arise, and the photograph shows how their above-ground roots bind the rubbish together.

Sometimes it is the *absence* of some common kind of creature that provokes inquiry. Thus there are no Amphibians on oceanic islands, and this is intelligible when we recall the fact that Amphibians have a natural antipathy to salt, and could not readily survive being washed on a floating tree, from the mainland. Rare exceptions to the Amphibian's antipathy to salt may occur, thus frogs have been reported from the sandy beach at Manila ; but this does not affect the general argument.

The second Natural History question is whether the insular plants and animals show any peculiarities connected with the peculiarities of the island. Thus, to take a simple case, the island of Madeira has an unusually high proportion of flightless beetles as compared with those, like cockchafers and ladybirds, that are given to flying about. May this be due, as Darwin suggested, to the fact that strong winds are very prevalent in Madeira, and that in the course of time the flying types have been swept out to sea. We know that the fauna and flora of Great Britain was profoundly changed by the glaciers that used to cover the greater part of the country. In a different direction the living creatures of some other islands have been much affected by volcanic eruptions. When the animals of a continental island are very different from those on the more or less adjacent mainland, as those of Madagascar from those of Africa, it means two things: that the separation took place very long ago, and that the external conditions of life on the island and on the mainland have become very different.

Photo: John J. Ward, F.E.S.

GREEK TORTOISE (*Testudo græca*).

This common Tortoise inhabits the Balkans, the Grecian Archipelago, and parts of Asia Minor, Syria and Italy. It may be six inches long; it feeds on juicy plants, but will learn to take bread soaked in milk. It likes the sun; it sleeps long; it burrows into the ground in winter; it pairs in spring, its two to four eggs are buried in the ground.

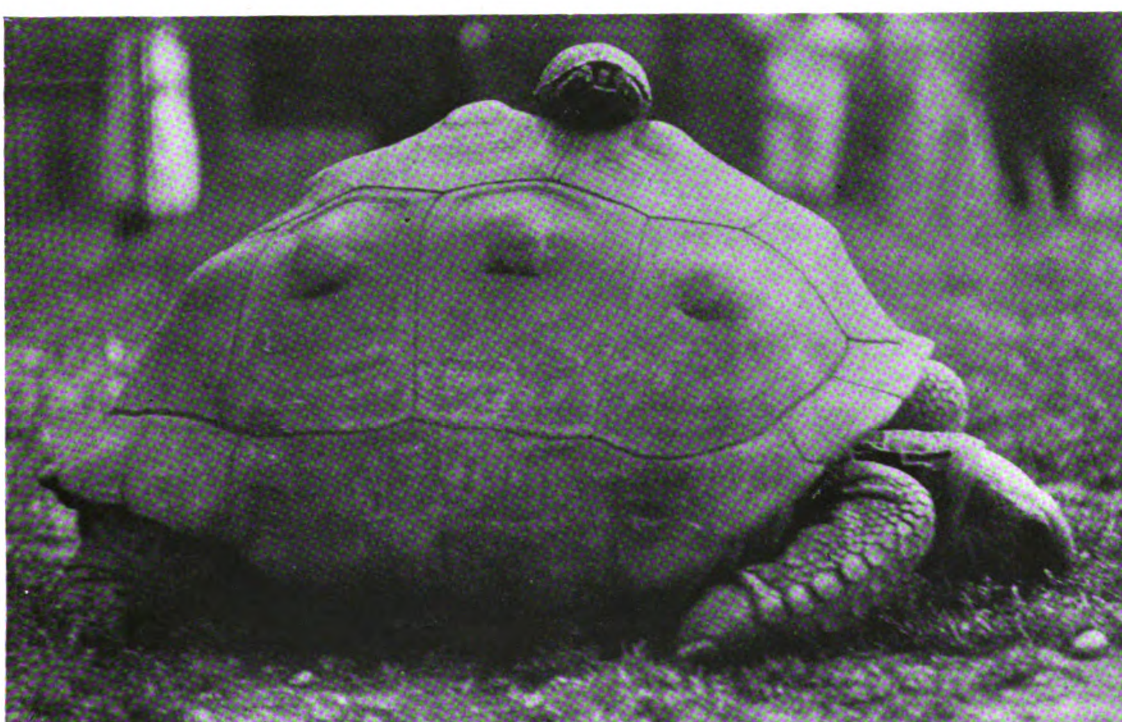

Photo: W. S. Berridge, F.Z.S.

THE ELEPHANTINE TORTOISE, WITH THE GREEK TORTOISE ON ITS BACK.

The Elephantine Tortoise (*Testudo elephantina*) was a native of the North Island of Aldabra, where it has been exterminated; but it lives still in the Seychelles, where it was introduced. A large specimen brought to Lord Rothschild at Tring was in 1897 40 inches in length and 52 inches over the curve of the back lengthwise.

When man took to interfering with geographical distribution, changes on islands often came about with extreme rapidity. Thus the introduction of goats on St. Helena meant the complete disappearance of most of the peculiar vegetation of the island.

The third Natural History question asks why so many islands have kinds of animals peculiar to them—kinds that do not occur anywhere else. Each island in the East Indies has its peculiarities in the way of monkeys, reptiles, freshwater fishes, and snails. Each island in Hawaii has its own species of Honey-sucker, and each forest its own land-snail. Each of the three groups of rookeries in the Behring Sea has its own species of fur-seal. There is a kind of wren peculiar to St. Kilda and a kind of vole peculiar to Orkney. Why should this be?

In general terms the answer is as follows: Most living creatures are variable. Offspring are often different from their parents, and the members of a family are often very unlike. In other words, new departures are of frequent occurrence, and it is easier for a new departure to establish itself on an island than in a district where there are no restrictions to crossing. When a breeder finds new departures that please him with their promise, he tries to pair them with others like themselves, or as like themselves as possible. In other words he brings about inbreeding in order to establish a new race. This inbreeding tends to occur in Nature when there is anything that restricts the range of crossing, and that is easier on an island than on the mainland.

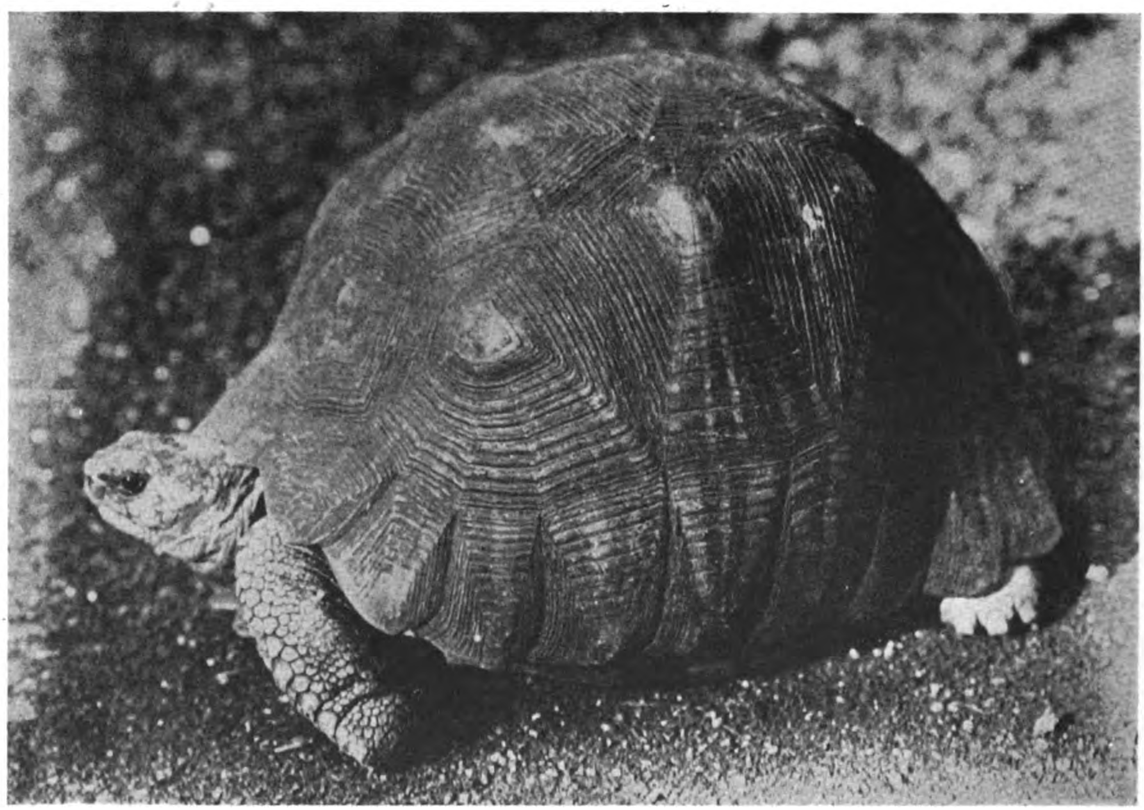

Photo: F. W. Bond.

RADIATE TORTOISE.

This Tortoise shows remarkably well the lines of growth on its horny scales, which overlie the bony carapace. These scales are products of the epidermis or outer-skin, fed by the dermis or under-skin, and the lines indicate successive increments season after season.

Tortoises.

Gilbert White tells of an aged tortoise, which he eventually acquired, that "as soon as the good old lady comes in sight who has waited on it for more than thirty years, it hobbles towards its benefactress with awkward alacrity." He comments on the fact that this "most abject of reptiles and torpid of beings distinguishes the hand that feeds it and is touched with the feelings of gratitude." But

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GIANT TORTOISE (*Testudo ephippium*) CLIMBING A HILL OF LAVA.

On Duncan Island, one of the Galapagos group, Mr. Beebe watched this Giant Tortoise climbing up a very steep and rough lava slope, which no ordinary tortoise could possibly surmount. It was greatly helped by its long and sharp claws. It was twenty-two inches in length, and weighed forty-two pounds.

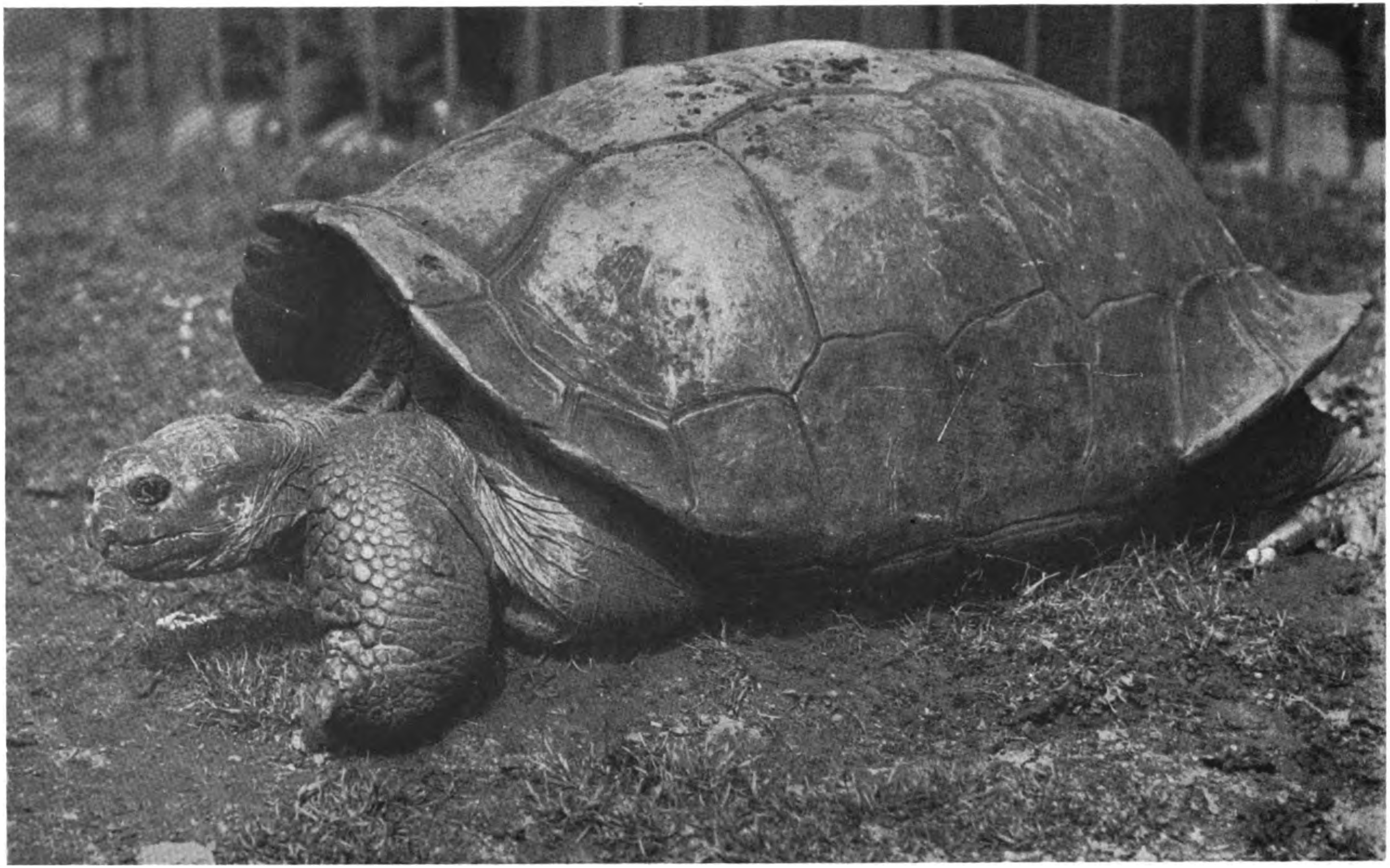


Photo: F. W. Bond.

GALAPAGOS GIANT TORTOISE.

No small Tortoises are found on the Galapagos Islands, but the giants, apart from size, are not very different from small species of Testudo, such as the Greek Tortoise. What is most notable is that each Galapagos island or group of adjacent islands evolved its own species of giant, except that the large Albemarle Island had four or five. Some years ago the number of Galapagos species of tortoise was estimated at fifteen, but several kinds have since disappeared.

even when we allow a good deal for the handicap imposed on the tortoise by the prevalent low temperature in a country like Britain—a foreign country to tortoises—it cannot be called a responsive pet!

Keeping the name "turtle" for the paddle-limbed Chelonians of the sea, such as the sources of turtle soup and of tortoiseshell combs, we may conveniently use the word "tortoise" for those that live on land, and "terrapin" for those that frequent freshwater. The kind oftenest kept in Britain is the Greek Tortoise (*Testudo græca*); the one Gilbert White studied was *Testudo ibera*, a nearly allied species. These Testudos are warmth-loving reptiles, fond of basking in the sunshine when it is not oppressively hot. They rise late and go to bed early; thus Gilbert White's pet used to retire at 4 p.m. in the long summer day and did not stir till late in the morning. It also buried itself in mould in November and remained in retreat till the middle of April—certainly the best thing for it to do in Great Britain. They do not sink into true "winter sleep" or hibernation, for that peculiar state is restricted to certain mammals; the reptile's condition is more like cold-coma or lethargy.

In spite of the asseverations of vendors, who declare that the tortoise will speedily clear off the "black beetles," the animal is a vegetarian. Though it may learn to take bread and milk and the like, it prefers lettuce and cabbage, dandelions and clover. Dr. Gadow watched hundreds very carefully in the course of years, and he never saw one of them eating slugs or earthworms, though this is often asserted. The Gopher tortoise, that burrows in sandy pine forests in the South-Eastern States of North America, eats not only grass and succulent herbs but the resin of the pine trees, which must be strong spice. On the whole, it may be said with confidence that Testudos are vegetarians of the stricter sort.

Tortoises seem to have adopted a "ca' canny" rule of life; they do everything with extreme deliberation. They feed slowly and they grow slowly—we can tell their age up to an uncertain limit by counting the concentric lines on the horny epidermic scales, for each ring means a summer's growth. Gilbert White noted that his tortoise (now enshrined in the British Museum) became lively in the month of June and indulged in energetic "amorous rambles"; but in the ordinary tenor of its life the tortoise takes good care to avoid all over-exertion.

When these cold volcanoes, the Galapagos Islands, far out in the Pacific, and yet not in the South Seas, were found over three centuries ago and called the Enchanted Isles, their discoverer described giant tortoises able to carry men upon their backs. Where these giants came from no one knows—they cannot stand the sea—but there are closely similar fossil forms entombed in Cuba. The Galapagos giants are usually regarded as a species of the genus Testudo to which the common Greek Tortoise belongs, and there seems to be nothing very remarkable about them except their size and longevity. There is one living in the New York Zoological Park thirty-eight and a half inches in length, with a weight of 268 pounds. For some of them a longevity of four or five hundred years is

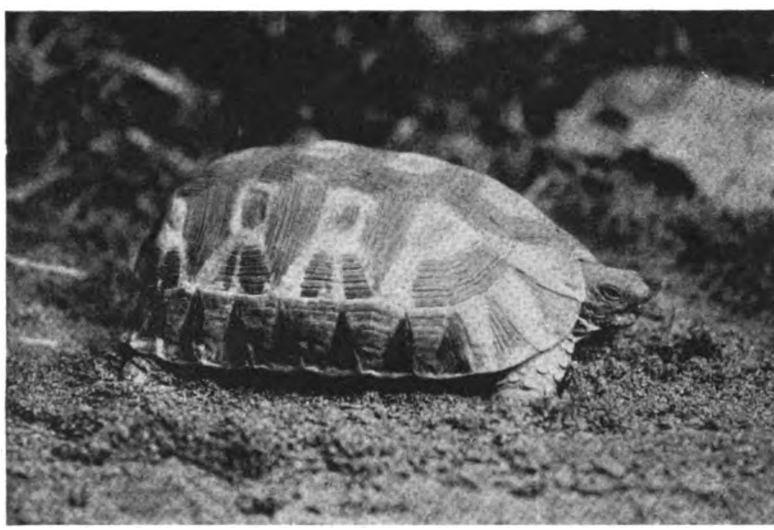


Photo: Stanley C. Johnson, M.A.

BRAZILIAN TORTOISE (*Testudo tabulata*).

This handsome Tortoise has a wide distribution in Tropical South America, and is sometimes brought to Britain as a curiosity. It may attain a length of almost two feet, and compared with the Greek Tortoise is rather flat on the back. It is a forest animal, feeding largely on fruits found on the ground. In captivity it enjoys fruits and milk-soaked bread.

claimed; but we have our doubts. There has been no careful study of the rings of growth on the scales; and as to the longevity of captive specimens, we know how easy it is to learn a substitution-trick from Brer Rabbit. Even at human levels it is not always easy to determine the length of life's tether in individual cases. Pensioners have been known to attain to a remarkable age, more suggestive of two generations than of one. But, after making many allowances, we seem to be justified in saying that giant tortoises lick animal creation in longevity. We wish we could say that they look as if they enjoyed it.

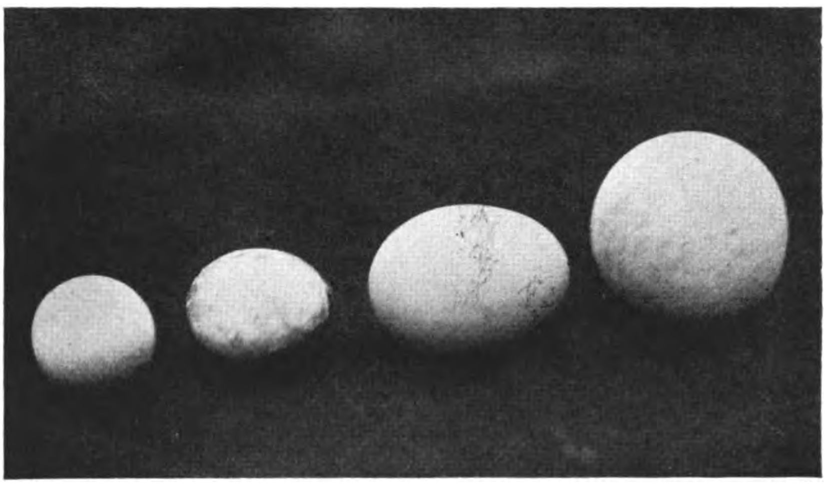


Photo: W. S. Berridge, F.Z.S.

EGGS OF CHELONIANS.

The inclusion of a hen's egg in this series gives a good idea of the comparative sizes of Chelonians' eggs. Reading from left to right the figures show:—1. The egg of the Snapping-turtle. 2. The egg of the Algerian Tortoise. 3. The egg of the hen. 4. The egg of the Elephantine Tortoise.

On his "Beagle" voyage Darwin visited the Galapagos and was greatly interested in the giant tortoises, perhaps most of all in the fact that different, though nearly related, forms occur on different islands. As he said, he was "brought near to the very act of creation." He timed one large fellow, and found that he walked at the rate of sixty yards in ten minutes, which is about four miles a day. Yet they cover considerable distances when they have a thirst which neither the succulent cactus, nor the green threads of pendulous lichen, nor the guayávita berries can slake. "Near the springs it was a curious spectacle to behold many of these huge creatures, one set eagerly travelling onwards with outstretched necks, and another set returning, after having drunk their fill." Darwin noted that the old ones "seem generally to die from accidents, as from falling down precipices; at least several of the inhabitants told me that they never found one dead without some evident cause." In other words, the giants live so long that they do not die a natural death. Yet the pathetic fact is that they will soon be exterminated. Every naturalist who has visited the islands has noticed, and perhaps deplored, the dwindling number of tortoises, and has then left the islands poorer.

The giant tortoises frequent the valleys where there are water-pools and succulent plants, but they climb the mountains in summer. The rocks on their favourite routes have become in some places so much smoothed that it is almost impossible to walk on them after a shower. Except in the midday heat and glare the tortoises may be seen or heard prowling about in their leisurely way, whether it is dark or light. In 1905 a visitor counted over thirty in three miles. It seems that the roving is in great part amorous, and the males utter barking cries which can be heard for three hundred yards in the forest. This seems to contradict the belief, to which Darwin refers, that the giants are absolutely deaf.

The eggs, larger than a hen's, are laid in layers in holes in the ground, and there may be eighteen or so in one nest. But the mother tortoise does not put all her eggs into one basket. There seems to be great juvenile mortality, the chief enemies of the young tortoises being buzzards and wild dogs. After they are a foot long they are more or less secure except from man, whose impious ruthlessness has been fatal. The flesh is unfortunately palatable, and the oil yielded by the fat used to command a good price. Scientific collecting is also to blame. So it has come about that some of the islands have only a few tortoises left, and in other cases there are none. In no case can we blink the discreditable

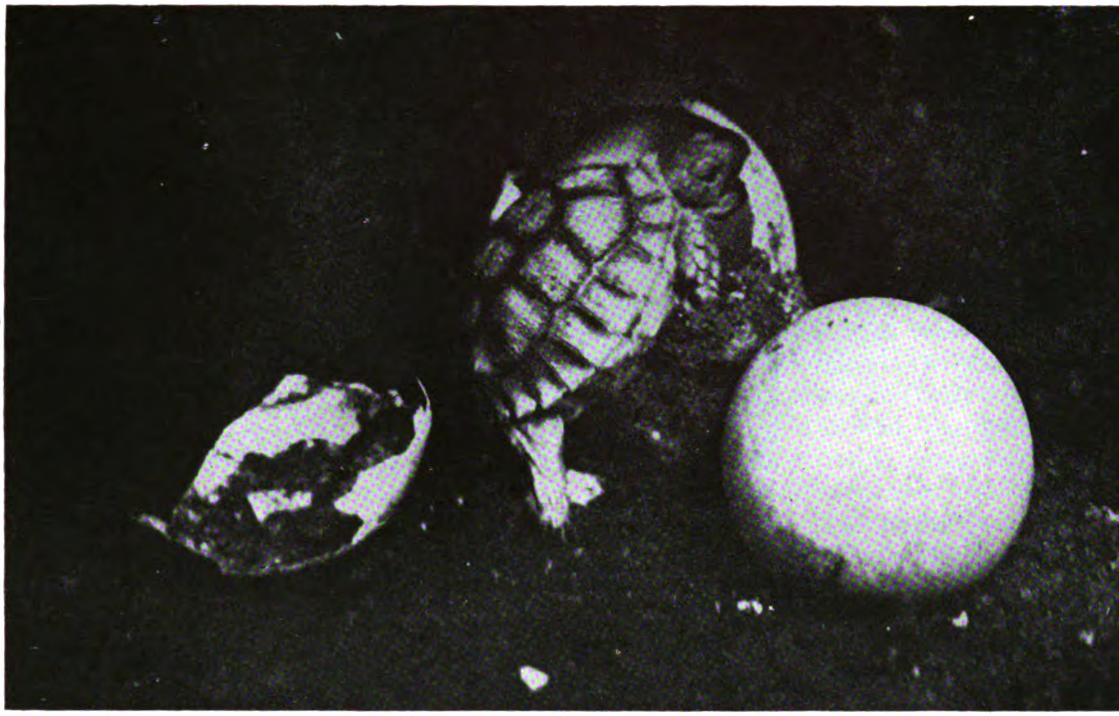


Photo: F. W. Bond.

BABY GROOVED TORTOISE (*Testudo calcarata*) EMERGING FROM THE EGG.

In all reptiles what is hatched out of the egg is a fully-formed miniature of the adult. The development is slow and there is plenty of yolk. Air passes through the porous egg-shell, first into the blood-vessels of the birth-robe called the allantois, and later on for a short time into the unhatched tortoise's lungs.

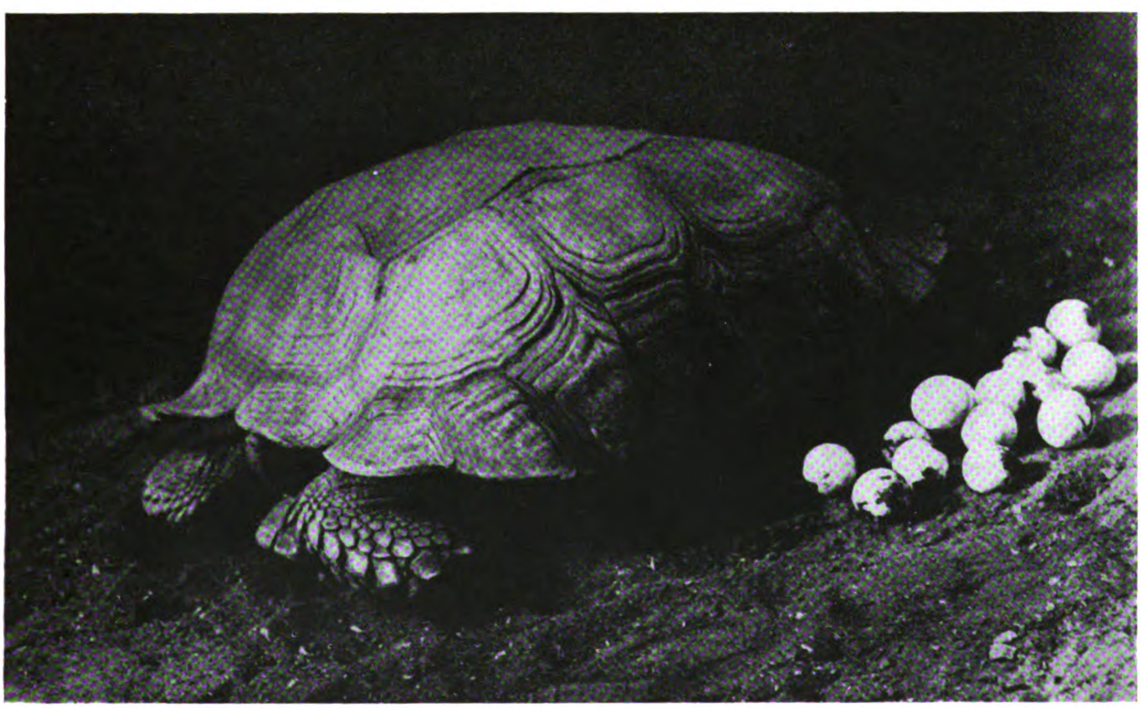


Photo: F. W. Bond.

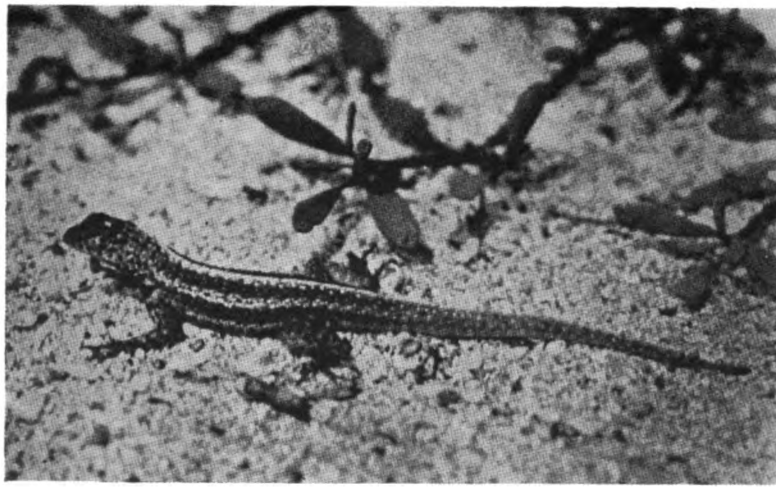
GROOVED TORTOISE (*Testudo calcarata*).

The eggs, which are shown at the side, are hard-shelled in the genus Testudo, but in Chelonians as an order there are all gradations from hard and calcareous to parchment-like and flexible.

fact that the days of the multi-centenarians are numbered.

Our regret over their passing is not because the giant tortoises are antiques like the "living fossil" that goes by the name of the New Zealand lizard or Sphenodon—the sole survivor of a very ancient reptilian race. The point about the Galapagos tortoises is that they afford or afforded such a fine object-lesson in species-making. Almost every island had, not so very long ago, its own species, to the number of fifteen altogether. Only on Albemarle Island is there more than one race. There seems no interpretation possible except the Darwinian one that all the species are derivations of one, which inhabited a single large island—now represented by the archipelago. When the island by submergence gave rise to the present discontinuous peaks, groups of similar tortoises were isolated, and variations in these inbreeding groups gave rise to the fifteen differentiated species. If it should seem more convenient to call them varieties, not species, it makes no difference to the general argument and lesson. As land tortoises soon drown in the sea, it is necessary to account for their presence on the original island, and the most plausible hypothesis is that there used to be a great land-bridge establishing a connection with Central America. It may be recalled that the Galapagos Islands lie on the Equator some 500 miles west of South America and 660 miles south of Costa Rica.

Giant tortoises may live over 150 years, and for some individuals, as we have mentioned, several centuries have been claimed. Yet there will soon be none of them! Dampier and other old travellers saw hosts; Mr. Beebe saw one! And it soon died after proving that it could swim for a while in the sea—affording material for hundreds of



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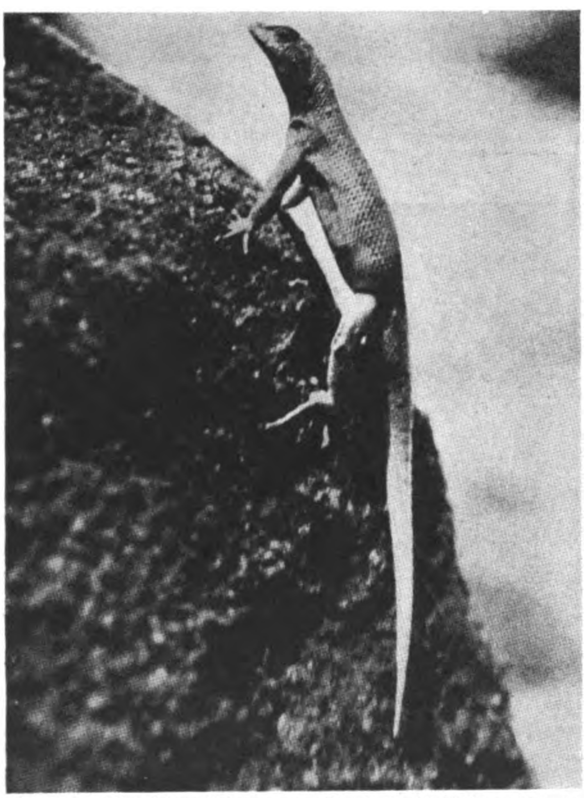
MALE TROPIDURUS LIZARD, FROM THE GALAPAGOS ISLANDS.

These little Lizards, four to eight inches in length, are brilliantly coloured, especially in the male. They are active and frolicsome, absurdly tame and inquisitive. They feed chiefly on insects and are preyed on by marauding birds. They have interesting courtship behaviour, nodding frantically at one another and inflating their body when excited.



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FEMALE TROPIDURUS LIZARD.

Here the female is standing high and just about to begin her energetic bowing. "The males were grey and brown above, mottled and banded with black, with the underparts a mixture of pink, red, and contrasting black. The females were usually more of a monochrome brown, with a brilliant slash of fiery scarlet over face, shoulders and sides." This illustrates "sex dimorphism."

feet of moving picture film. Man is not a good trustee.

It is congruent with the slow life of tortoises that many of them should live to a great age. They are slow in ageing, slow in dying! Gilbert White's tortoise survived its master about a year, dying in 1794, after an existence in England of about fifty-four years, the last fourteen of which were spent at Selborne. A few centenarians have been known. In 1766 five giant tortoises were brought from the Seychelles to Mauritius, and one of these was living at the beginning of this century. We have not heard of it lately, but in 1901 Dr. Gadow reported that "though nearly blind it was otherwise of regular habits and in good health." Its shell length was over a yard, and it could carry two men on its back.

Slow in so many respects, tortoises are not quick in the uptake. The brain is almost ridiculously small compared with the size of the skull. But we suppose they are as clever as they need to be, else they would not have lasted so long. They learn to discriminate between people, and they have a distinct aptitude for geography. They master their region, and can return home from a considerable distance. They remember their particular winter quarters, even when it is in a rather out-of-the-way place. A terrapin has been known to solve the problem of a maze, which is at least evidence of profiting by experience. There is a well-authenticated case of common tortoises craning their necks to listen to the town band playing on the square adjoining their garden, but we do not know whether this could be cited as evidence of intelligence. Ordinary tortoises do not speak much, but they have their little "piping" at the breeding season, the miniature echo of the hoarse roar or bellow of the male Giant Tortoise of Chatham Island, which Darwin heard at a distance of more than a hundred yards. Common tortoises lay two to four white-shelled eggs, like those of pigeons, and bury them in the loose soil. We have never heard of any parental care.

The slow-going tenacious vitality of tortoises and their kin is expressed in the well-known "local life" of parts of their body. Thus the heart of the edible turtle, kept in appropriate surroundings, retains the power of beating for a week or more after the flesh of the animal has been made into soup. This is very remarkable, but we think the most remarkable thing about the tortoise is its armour. Gilbert White speaks of it somewhat dubiously—"Pitiable seems the condition of this poor embarrassed reptile;

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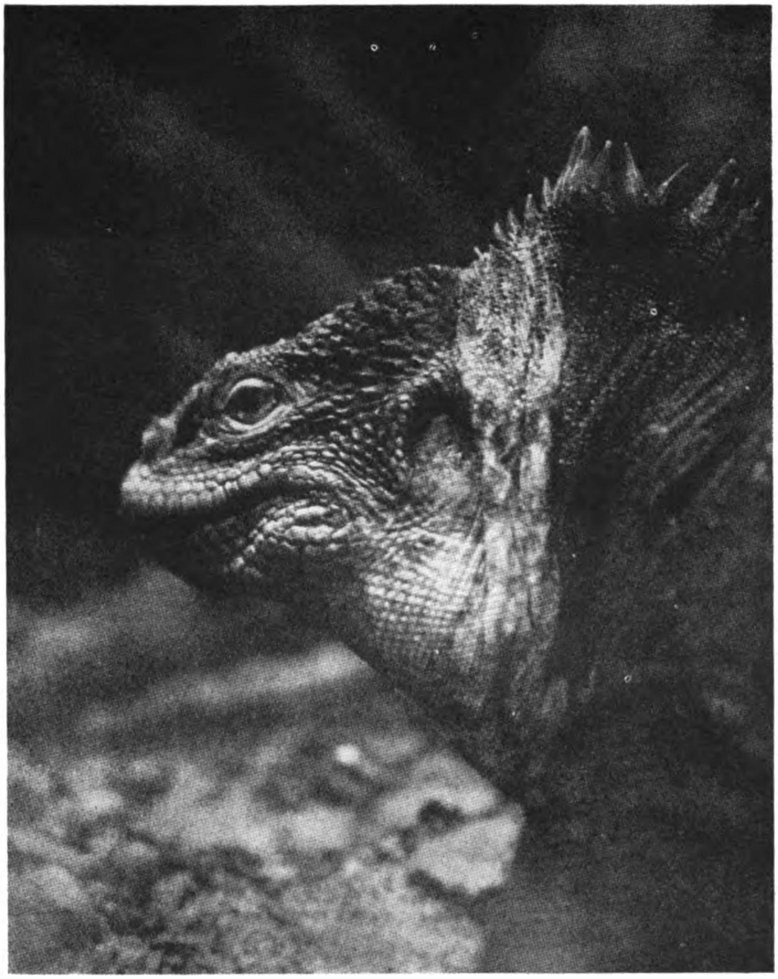
FRIGATE BIRD (*Fregata aquila*).

The male on the nest with the brilliant scarlet throat pouch fully distended. It is like a balloon and the beak rests on the top of it "as if on a pneumatic pillow." Mr. Beebe noticed that when the male settles down to brooding, the balloon shrinks to "an unlovely crimson mass of folded skin." The family of Frigate Birds is related to cormorants, solan geese, albatrosses, and pelicans.



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HEAD OF GIANT LAND IGUANA OF THE GALAPAGOS.

These creatures, as Mr. Beebe says, recall extinct reptiles in their great size and majestic mien. They sprawl in the shade and glow with colour, but when they are seriously disturbed they seek sanctuary in a thorn bush or in their deep burrows. Unlike Amblyrhynchus, their marine cousin, they accepted captivity without any ado, and in a short time they were eating lettuce and bananas from the explorer's hand.

to be cased in a suit of ponderous armour, which he cannot lay aside; to be imprisoned, as it were, within his own shell"; but the other side of these intricate shields is that they confer invulnerability. Is any animal in Europe able to make anything of the Greek tortoise, except the Greek eagle, which lifts the creature in its talons to a great height and lets it fall on the rocks below. For all ordinary contingencies the tortoise is safe; boxed in above, boxed in below, able to draw in its head and tail and limbs, with a shell built in the principle of an arch or tunnel, the tortoise is able to cultivate a masterly indifference to assault. Even more remarkable, however, is the extraordinarily intricate way in which elements of exoskeleton and endoskeleton are soldered and welded together into what is to the tortoise a growing and moving fortification and to us an anatomical puzzle. (1) On the outside above and below there are the horny, epidermic scales. (2) In the middle line of the dorsal carapace there is a row of bones made out of the flattened tips (neural spines) of the vertebræ. (3) Outside these there is a row of under-skin bones—dermal scutes—which are plastered on to the neural spines. (4) The sides of the dorsal carapace are made of the flattened-out, rigidly fixed ribs. (5) Outside these more scutes are plastered on—the costals. (6) The ventral shield, or plastron, consists of bony plates—badly called "abdominal ribs"—which ossify underneath the skin of the abdomen. (7) But the front part of this ventral shield is believed by some authorities to represent the collar-bone. There is no breast-bone. What intricacy of 'make-up'!

Speaking of the tortoises of the Galapagos Islands leads us to picture some of the other inhabitants. Thus there are the lava lizards, species of Tropidurus, alert lithe creatures, four to eight inches long, appropriately dressed in grey and black and scarlet-ash, and lava and flame. They are always on the outlook for marauding birds, but they are absurdly inquisitive and unafraid of man. "When pursued, they would impudently pause until almost within reach, at the last moment going through a great show of intimidation, nodding the whole head and body violently up and down, and expanding their scarlet and black pouch to its fullest." Mr. Beebe observed the ongoings of a

big male who was courting a scarlet-throated female sunning herself on a patch of lava. " He crept a little nearer and nodded again, whereupon the lady lizard rose as high as possible upon all four legs, making them look like straight little sticks, arched her body, blew herself up with air until she lost all semblance to a lizard, and, turning her head slowly, spat upon her admirer. He turned, nonchalantly caught a fly, and sadly made his way elsewhere."

The giant marine lizard Amblyrhynchus, which we have already described, has an inland cousin called Conolophus. It keeps to the terrestrial tradition of the Iguanid family to which they both belong. Conolophus is gorgeously coloured in yellow, gold, red, terra-cotta, brown and black, and attains a length of about a yard—a truly splendid lizard. It has a hot temper and bites fiercely. On two occasions Mr. Beebe observed an interesting episode in the life of the giant inland lizard. It came nearer intelligence than he had ever observed in any other reptile. The lizard was standing with one of its friends at the foot of a spiny cactus (Opuntia), and it struck the base slowly but repeatedly with one fore-foot. Nothing happened at first, but the lizard continued striking firmly, and, finally, two fruits fell at once. Whereupon *the other* lizard rushed up and gulped down both, spines and all. The intelligently industrious lizard remonstrated with its companion—representative of the leisured classes—but it was too late! So it went off in a bad temper, and lay down in the shade, perhaps to dream of a better world where industry is not robbed of the fruits of its labours. It is more than surprising that these lizards habitually eat pieces of cactus bearing spines as long as needles and almost as hard. At other times they enjoy the golden petals of the cactus flowers. What a contrast in meals!

Apart from a few mice and a bat, there are no native land mammals on the Galapagos Islands, but there are some very interesting birds. The male Frigate-bird is, perhaps, the climax. It is remarkable for its inflatable throat pouch which

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GIANT LAND IGUANA (*Conolophus subcristatus*).

This magnificent Lizard is the first cousin of the marine Amblyrhynchus, also of the Galapagos Islands; but it has become adapted to live in the interior, where it feeds very largely on the fruit of the Prickly Pear. The photograph shows it sleeping at midday in the narrow line of shade of a tree. It may exceed a yard in length, and has a gorgeous livery of yellow, green, grey, terra-cotta and black.

can be blown up till it completely hides the rest of the bird. "His plumage was dull-brown with a mantle of glossy-green hackles. Eyes, beak, and feet were dull, but out of this sombreness, like fire out of lava, billowed the burning scarlet of the enormous breast pouch." This extraordinary bird may be seen asleep with his beak resting on the top of his pneumatic pillow, or actually soaring in a somewhat wobbly fashion which betrays the fact that he has some difficulty in balancing his balloon. The inflation is due to certain air-sacs in the neck, which are connected, as in other birds, with the lungs. There is no inflation in the female, who has a breast of white feathers. There can be no doubt that the male's puffed-upness is part of the business of courtship, for it disappears when he settles down to family affairs and takes his share in brooding. But the courtship is worthy of these islands which used to be called "Enchanted." Mr. Beebe tells how the male bird bent his head back until it sank between his shoulders, the red balloon projecting straight upward, and the long angular wings spread over the surrounding bushes. The female flew overhead. "The entire body rolled from side to side, as if in agony, while the apparently dying bird gave vent to a remarkable sweet series of notes, as liquid as the distant cry of a loon, as resonant as that of an owl. In our human, inadequate, verbal vocality, I can only record it as *kew—kew—kew—kew—kew—kew!* In a higher tone the female answered him from the sky, *oo—oo—oo—oo—oo—oo!*" To read Mr. Beebe's "Galapagos: World's End"—unfortunately, a very expensive book—is as Professor Henry Fairfield Osborn says in his foreword, "like rubbing the Aladdin's lamp of science."

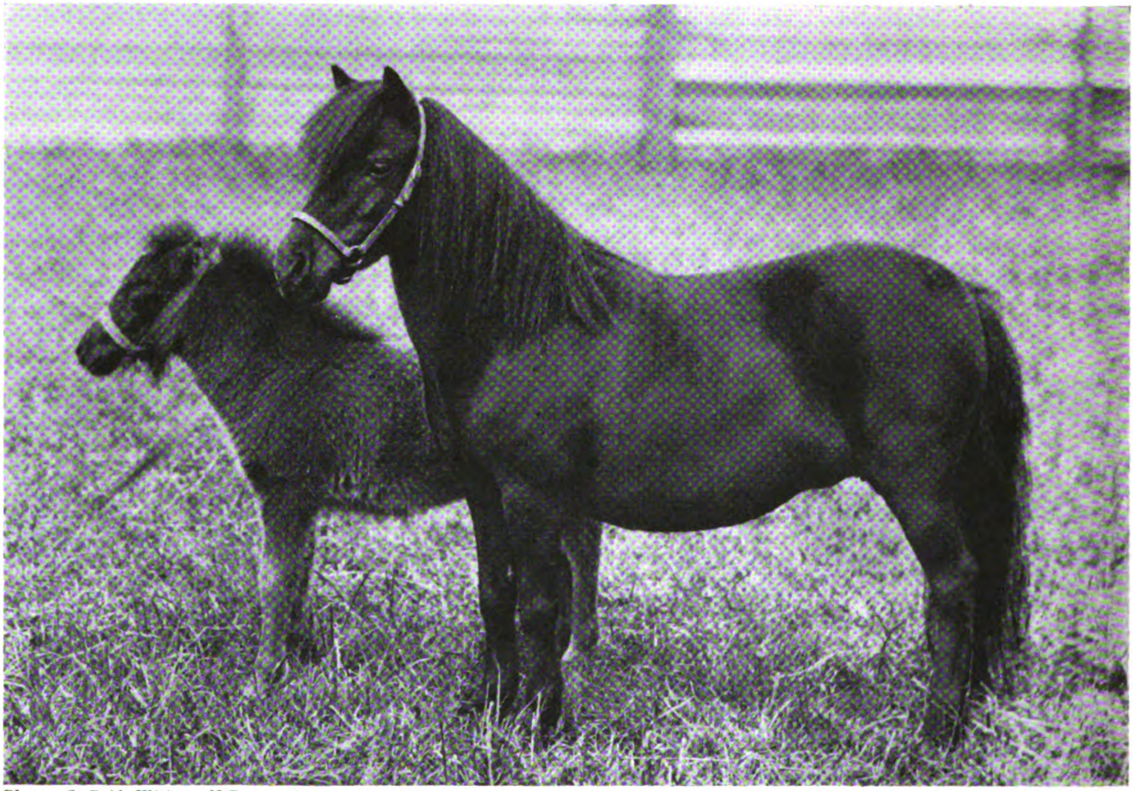


Photo: C. Reid, Wishaw, N.B.

SHETLAND PONIES, MARE AND FOAL.

At the beginning of the eighteenth century a visitor wrote: "This Country produces little Horses, commonly call'd Shelties, and they are very sprightly, tho' the least of their kind to be seen anywhere; they are lower in stature than those of Orkney, and it is common for a man of ordinary strength to lift a Sheltie from the ground: yet this little creature is able to carry double."

There is something peculiarly fascinating in the Shetland Pony. No one can wish to see a prettier sight than a herd of them having a race by themselves in a field. It is more than their dainty size that we admire, or the graceful

Photo: C. Reid, Wishaw, N.B.

SHETLAND PONIES.

As buried bones and rock-drawings prove, small-sized ponies lived in the Shetland Islands before the Scandinavian invasion and settlement of the ninth and subsequent centuries. While there seems to be a Scandinavian strain in the present-day "Shelties," there is evidence of an Oriental cross, or in any case of something different from the small ponies of Norway and Sweden. The popular idea that the "Shelties" were dwarfed by starvation and other severe conditions of life is not tenable.

shape, or the poise of the alert head. We are fascinated by an individuality—at once of brains and of character. As one of its admirers says: "The Shetland is the most beautiful, the most reliable in disposition, the hardiest, the freest from defect, and the pony that suffers the least from neglect of any of the known breeds. He is absolutely without the taint of a vicious trait. He is very companionable, and is recognised as the only safe child's pony. The amount of work he will do is prodigious."

The "Sheltie."

The Sheltie existed in Shetland in prehistoric times, as sculptured stones show: and there is much to be said for the view that it represents a *mutation*—a dwarfish freak endowed with stable constitution, well-suited to endure hardships. Just as there have arisen pigmy elephants and pigmy hippopotami and pigmy men, so there have arisen pigmy horses. Whether this particular type of pony arose in Shetland or elsewhere, e.g., Scandinavia, we do not know. There seems almost no warrant for regarding the Sheltie as a hark-back to the very diminutive ancestral horses, some of which were no bigger than foxes. That was millions of years ago, and there is nothing of the reversionary about the Sheltie. Nor can we favour the idea that inadequate nutrition before or after birth led to dwarfing, for that sort of enforced dwarfing is not usually heritable. Moreover, there is nothing of the degenerate about the Shetland Pony; it is an almost perfect creature. To interpret the small size as the direct result of the strenuous conditions of Shetland life is tempting, but there is very little evidence that this is the way evolution works. Moreover, the evidence of breeders seem clear that the stature (three feet or so at the withers) does not increase when the ponies are reared in luxury. With due care they remain dwarfs when brought up far away from Shetland, and with all the food and shelter they want.

We submit that Shelties originated like other strong, well-proportioned, intelligent dwarfs, apart from any direct connection with severe climate and short commons. Perhaps the dwarfness was wrapped up with a variation in the degree of development of the pituitary body or some other ductless gland which has to do with the regulation of growth. There is some evidence that certain extinct giants among animals had a large pituitary body.

But while we do not believe that the scanty pasture and the exposure to cold and stormy weather can account for its peculiarities, we hasten to admit that its peculiarities favour survival in such strenuous conditions, and may have been accentuated by inbreeding and artificial selection. Thus there is undoubtedly protection from the cold in the abundant mane and tail, and "that waterproof double coat of thick fur and long hair which alone can maintain warmth in wind and rain and mist." There is also strength of bone and muscle: "It is common for a man of ordinary strength to lift a Sheltie from the ground: yet this little creature is able to carry double!" The Sheltie has also a very good digestion—an ability to make the most of rough fare, such as even the jetsam of the sea may afford. In their charming monograph on the Shetland pony, Mr. and Mrs. Douglas point out that the hard conditions in the North also "favoured that docility and sweetness of temper which made the Shetland pony more truly domestic than any other horse, because they make it essential that the pony should live in intimate dependence on its owner." And besides all these fitnesses there is the clever wit of the creature, and its pluck, "metall past belief."

Perhaps some of the old chroniclers were a little exuberant in recounting the capacities of Shetland ponies, for we find difficulty with the record of one that could carry "an able man and a woman behind him eight miles forward and as many back," as also of these which "climb up braes upon their knees, when otherwise they could not get the height overcome." This is the right spirit, no doubt, but the Shetland pony requires no fictitious praise. It is a singularly perfect and engaging creature, in whose emergence Nature's art and Man's have co-operated successfully.

The Shetland pony used to be of great service in the islands in carrying home the peat or in bringing the sea-ware from the shore; but the introduction of wheeled vehicles has greatly lessened its importance in these connections. Then came the period when the ponies began to be much employed in pits—a utilisation which led to great improvements in breeding.

Specially drawn for this work by Warwick Reynolds, R.S.W.

THE GREY SEAL (*Halichœrus grypus*)

The Grey Seal is often seen in the Hebrides and the Shetlands, a variably greyish creature with dark blotches, and much lighter below. The male is about eight feet long—a very handsome animal. This seal has no under-fur, so it does not yield "seal skin." They usually occur in pairs or in family parties, but small groups are sometimes seen. The young ones are white until they are able to take to the water

It seems very inartistic that the Shelties should become dwellers in darkness, but it is not true that they become blind. They are usually in good condition in the mines, and they reward kindly treatment with affection. We suppose, however, that this utilisation will also cease, and that the Shetland pony will then be mainly reserved for the height of its calling, which is to be a child's mount and one of the child's teachers. "With a little luck," the Douglases write, "father and son may learn to ride the same Sheltie." For to its many virtues it adds that of longevity, sometimes attaining to thirty-five years, which is a good measure of a generation. But we like the way in which Mr. and Mrs. Douglas round off their study. It is not his usefulness that binds the Sheltie's lovers to him: "Rather it is himself—his wisdom and his courage, his companionable ways, his gay and willing service. He has the dual charm of a creature at once wild and tame—wild in his strong instincts, his hardihood, and his independence—domestic in his wisdom and sweet temper, his friendly confidence in mankind, and his subtle powers of imagination." That is well said.

Only once have we seen the devil in the Sheltie—the wild thing in its eyes. A troop of them came trotting down the highway, looking extraordinarily beautiful, almost like fairy-horses. A great dray-horse was standing with its load on a side-path abutting on the main road, and one of the sprites ran up to him, and, reaching high, fetched him a kiss on his surly lips. He said something nasty, we suppose, for instantaneously she wheeled and struck him with her hind-hoofs in the mouth. She had the very devil in her eye!

Photo: C. J. King.

GREY SEAL NURSERY (ISLES OF SCILLY).

The Grey Seal (*Halichœrus grypus*) is restricted to the shores of the North Atlantic, and is commoner in the North of Scotland than on the English coasts. They breed on the outer Hebrides in remote rocky inlets and caves, and there are a few breeding haunts as far south as Cornwall and Scilly. The young ones do not move much for three weeks; when they are not sucking they are sleeping!

While dolphins, porpoises, and whales or Cetaceans generally, are rightly ranked among the conquerors of the Open Sea, the seals are to be thought of in connection with islands and the seashore. They have not attained to the Cetacean's independence of dry land.

Seals on the Shore. The Friendly Seal.

There is no doubt that seals are the descendants of terrestrial carnivores that took to a seafaring life. They betray their land origin in coming ashore to rest and sleep and to bring forth their young; but the great adventure of becoming marine must have been made long ages ago, for there are many aquatic adaptations

Photo: F. W. Bond.

COMMON SEAL (*Phoca vitulina*).

The Common Seal is hardly more than half the size of the Grey Seal, but the general colour is much the same—yellowish-grey spotted with black and brown, and silvery grey beneath. It is unlike the Grey Seal in being gregarious and seems to be a much livelier animal, tameable and attracted to music. It has an under-fur which makes its skin valuable and its fat yields oil. There is usually only a single young one at a time.

in the seal's body. The somewhat conical shape is suited for swift movements in the water; there is reduction of friction in the absence of ear-trumpets, in the close-set fur, and in the way the hind-legs are thrown back beside the short tail. The nostrils can be closed under water; the sensitive whisker hairs are of use in the dark diving; the structure of the eye is also suited for the gloom in deep zones. The blubber beneath the skin makes the seal more buoyant; it helps to conserve the precious animal heat; and it is a store of reserve material for days when it is too stormy to fish. The teeth, with their tips tilted backwards, serve to grip the slippery booty. Both hands and feet are webbed, and clawed as well. No doubt the seal is a bundle of fitnesses.

The Common Seal and the Grey Seal may be called residents on British shores, and there are four others which are known as visitors. The Common Seal may go far up a river and even reach an inland lake; thus it has been seen at Perth and in Loch Awe.

The Common Seal can swim at the rate of ten miles an hour, about half as quickly as a dolphin, and the instantaneousness of its turning is like magic. A fish—like flounder, or whiting, or salmon—has no chance when a seal has made up its mind. When we watch a dog swimming we see that it treads the water with its fore and hind limbs; but this is not the seal's method. It keeps its fore-limbs close to its breast, except when turning or steering, and it swims like a fish by means of its very muscular posterior body, aided by the firmly appressed legs, which form the hind part of the propeller. A propeller, however, that does not turn round; it simply dislodges masses of water first to one side and then to another, with lightning-like quickness. The large Grey Seal is not nearly so fast, and it has, therefore, to attend to more slowly moving fishes, like halibut, which it seeks out far below "full fathoms five."

The movements of seals on the sand are very quaint. They hirple along at the rate of about three miles an hour. The creature raises its shoulders, depresses its head, sticks its fore-

flippers outwards in the sand, drags its body forward (sometimes helped by a jerk from the hind-legs), sinks prone, and begins again. What catches the eye is the alternate arching and flattening of the body. A young grey seal has been known to make a land journey of half a mile to a cottage, and when it was taken back to the sea it repeated the visit next day. Short land journeys have often been recorded for the common seal, especially in the case of tame ones, which refuse to be sent back to the sea. There seems to be in seals something of the "local attachment" and "homing capacity" which is exhibited by cats, but most of the data remain unfortunately at the level of anecdotes. Common seals have their favourite resting rocks, and the grey seal has favourite spots in the water, where it persists for hours and days.

The Common Seal is still common. It has made a success of life along the coasts of the North Atlantic and the North Pacific. It is more Scotch than English, and there are quiet places where one can see a hundred in a day. Of late large numbers have appeared in the Wash. When we go a-fishing in the evening on one of the western sea-lochs, the seals come about companionably, raising their bullet heads above the surface, and staring at us with their large liquid eyes. They are very quick of hearing, and will gather to an unusual sound. It seems to be rather from curiosity, however, than from a love of music, for they will come to a concertina as well as to a flute; and when they have become accustomed to the sounds they cease to be interested. It may be, however, that this only means that they wish a change of tune. Indeed, we are inclined to be generous, for seals have fine brains, and their undoubted capacity for becoming attached to persons and places shows that the emotional string is well developed. This is seen also in their playfulness, in their "follow-my-leader" games, in the lovingness of the mothers, and, perhaps, in the way they kiss one another.

Common seals are at once polygamous and polyandrous, so the less we say about their mating relations the better. September is the breeding time, and four or five months before that the sexes have been living for the most part separately. The mothers have their pups in June, after carrying them in the womb for nine months. They suckle them for about eight weeks. The males do a good deal of fighting in the latter part of August.

Whereas dolphins and other Cetaceans bring forth their young in the water, the seals, which are more recent colonists of the sea, bring forth their young on land. The young of the common seal sheds its first coat of (white) hair before it is born; it begins its independent life with its *second* coat, which is darkish. The pup can take to the water the day of its birth, but it needs

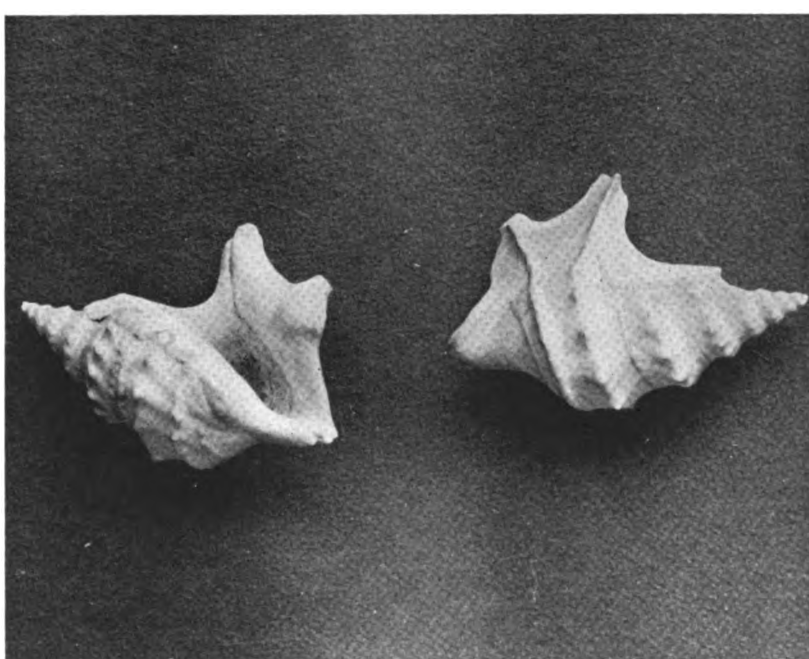


Photo: M. H. Crawford.

PELICAN'S-FOOT SHELL (*Aporrhais pes-pelecani*).

A strong turreted shell with knobbed whorls, not uncommon on British coasts. It is in some ways intermediate between the top-shells (Trochus) with an entire circular mouth to the shell, and the dog-whelks with a notched aperture. In the Pelican's-foot there is a short notch or canal and several broad lobes when fully formed. The living animal is beautifully flecked with scarlet.

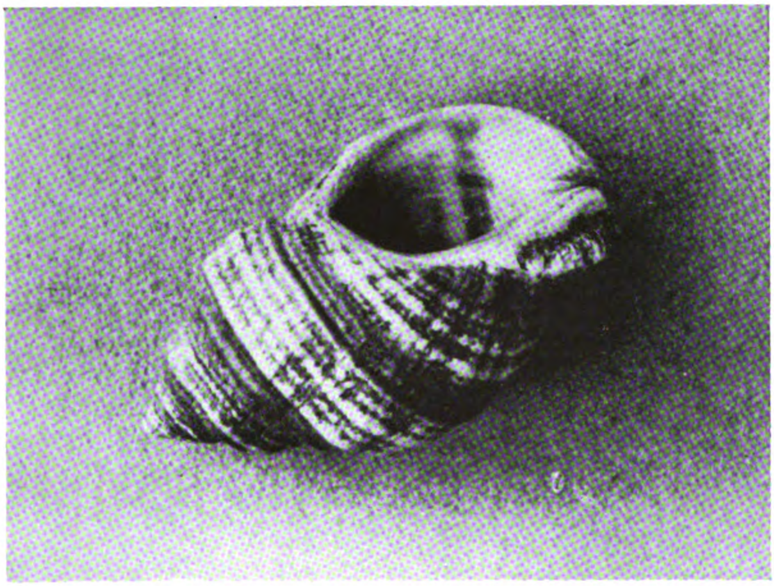


Photo: M. H. Crawford.

THE COMMONEST DOG-WHELK (*Purpura lapillus*).

A very common and very variable shore Gastropod. As its name Purpura suggests, it yields a purple dye similar to the famous Tyrian purple which was furnished by several of its many allies. Its vase-like egg-cases are fastened in clusters to the low-tide rocks.

long rests ashore and much mothering, which it certainly gets.

The Common Seal has no enemy save man and its own big cousin—the Grey Seal. Unlike the dolphins and porpoises, the seals must have their rest on land. They take advantage of waves to get up on a rocky shelf; they use their nails in clambering; they adjust themselves so as to slip into the sea in an instant; they sometimes post sentinels; but they often fall asleep. And it is then, and at the breeding time, that man often clubs them. It is a strange inconsistency that although man cannot deny that seals have a certain fascination for him, he cannot resist killing them when he gets a chance. He calls them lost souls and fallen angels, mermaids and mermen; he has invented pretty stories about them and cherished superstitions; but he kills them at their play and in their sleep, or when the mother comes ashore to comfort her young. We can hear the seal's melancholy cry!

Shells on the Shore.

Superior persons sometimes speak condescendingly of the children who gather shells on the shore. Perhaps they are forgetting what Sir Isaac Newton said on this matter: "To myself it seems that I have been but as a child playing on the sea-shore; now finding some pebble rather more polished, and now some shell rather more agreeably variegated than another, while the immense ocean of truth extended itself unexplored before me." This sentence of itself, with its fine humility, is enough to dignify shell-gathering for all time.

The world is full of beauty-feasts spread out generously before us, and while it profits little to compare one with another, the shells on the shore need not yield precedence to any. A corner of an Alpine meadow in flowering time, the transfiguration of the trees in autumn, the chaffinches on the hedge, the Shetland ponies racing in the field, the cut opals in a bowl

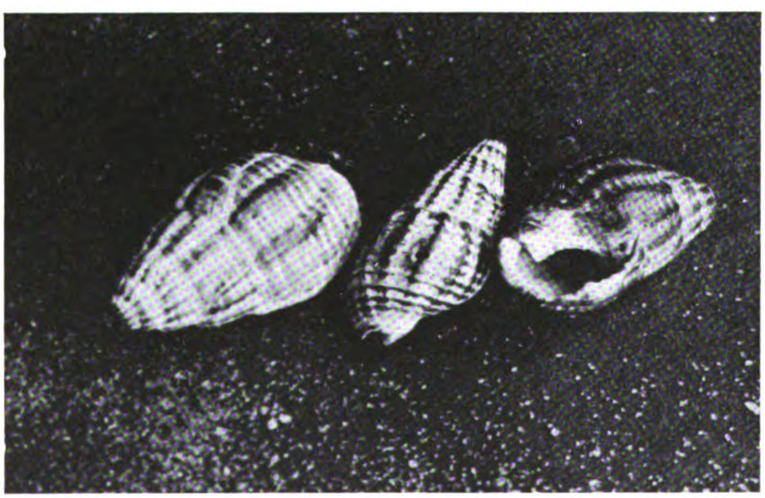


Photo: M. H. Crawford.

THE SPOTTED DOG-WHELK (*Nassa incrassata*).

A beautifully marked shell, common on British shores. There are rounded whorls crossed by protruding ribs. The middle and right photographs show the notch or canal at the mouth of the shell. In this, during life, there lies a breathing-tube. All Gastropods that show this are carnivorous.

of water, and a thousand and one delightful sights—all are joys for ever; but we are not ashamed of our little shore-pool in which we have gathered a handful of shells. Even when they are high and dry, what dreams of beauty they are! These pleasing curves are the frozen music of a harmonious life—far-off hints of beautiful houses. These concentric lines are the ripple-marks of rhythmic growth, like the rings in the trunk of a tree or the zones on the scale of a fish. These nuances of colour, grading into each other, are the registrations of the ebb and flow of vital tides, just as the cross-bars on the feathers of Birds of Prey record the diurnal ups and downs of blood-pressure during the period of feather-making.

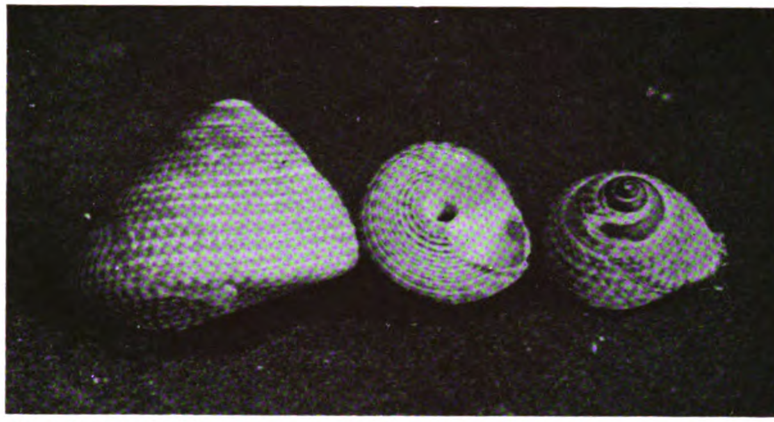


Photo: M. H Crawford.

A "PEARLY TOP" (*Trochus cinerarius*).

This beautiful shell, with a flat base and numerous whorls, is common on some British coasts. The mouth of the shell is circular and intact, without any notch; and this goes with a vegetarian habit. This greyish-pink species shows a hole in the middle of the base.

And just as one likes the irregularities of old masonry, which give it a stamp of individuality, so one enjoys comparing different specimens of the same kind of shell, since one often discovers personal idiosyncrasies—the answers-back that the shell-maker made to the smiles and frowns of circumstance. We venture to suggest that for the feeding of the eyes of those who can rarely see the shore, there is an inexhaustible supply in a box of shells—rich in what one might call sensory vitamines.

The common shells of the shore are either bivalves, like cockles and mussels, oysters and clams; or univalves (Gastropods), like whelk and

Photo: M. H. Crawford.

COMMON "PEARLY TOPS" (*Trochus zizyphinus*).

This "top-shell" is larger than the species shown above, and has more whorls. There is no hole in the base; the shell is spotted with rose. When these top-shells are much worn on the beach, the outer layer disappears and the silvery mother-of-pearl is exposed.

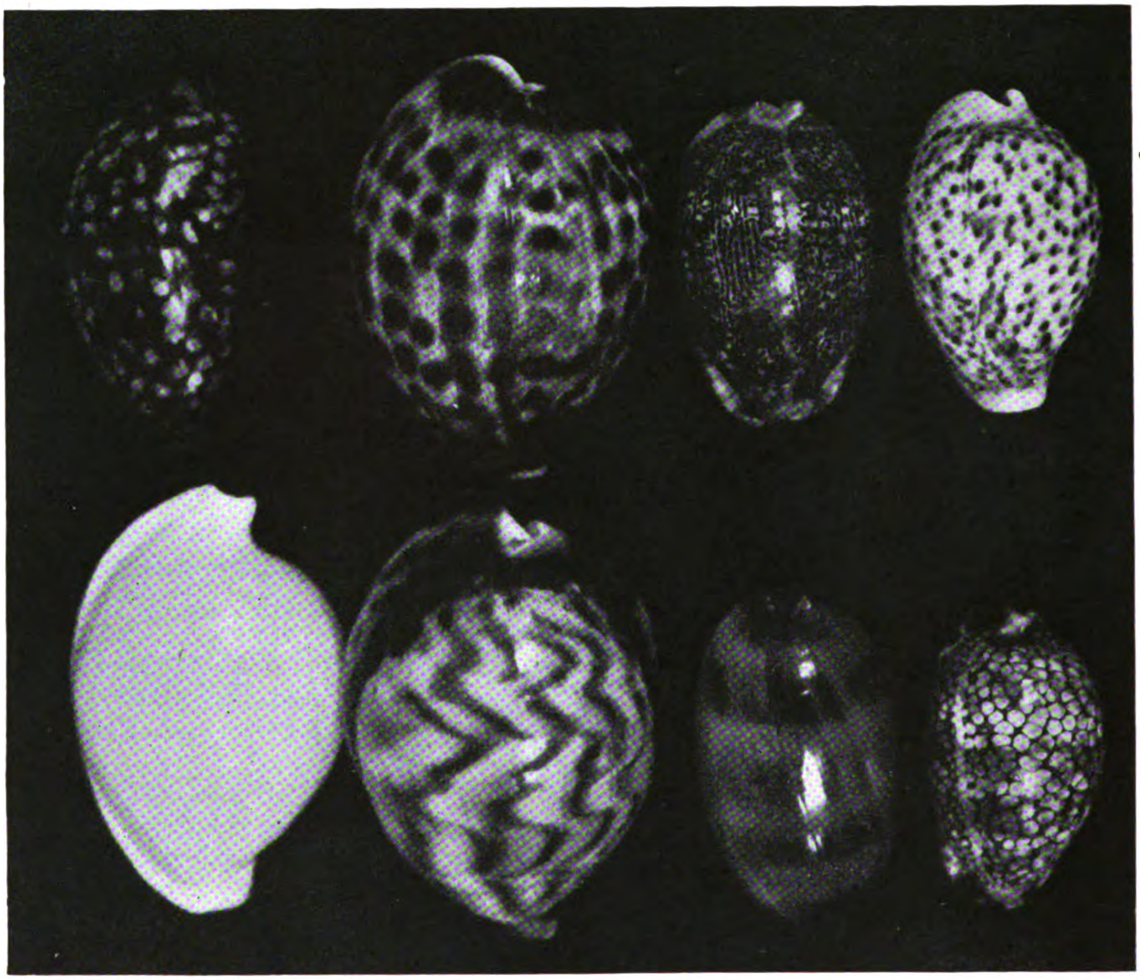


Photo: John J. Ward, F.E.S.

COWRY SHELLS.

There are many different species of Cowry or Cypræa, including the Money Cowry (*Cypræa moneta*), and they are famous for the variety of their beautiful markings and colours. The young form has a thin spiral shell with a conspicuous apex, but as growth goes on, the spire is overlapped and hidden, leaving for a long time some evidence of itself at one end. During life there are two folds of skin or mantle reflected over the shell.

periwinkle, cowrie, limpet, and ormer. Occasionally one finds the unique cylindrical Elephant's Tusk shell (Dentalium) washed up from a considerable depth; and not uncommon on the rocks are the primitive Chitons, with eight shell-pieces fitting flexibly one on another over the animal's back.

What are the characters in which the shells of all these Molluscs agree? The shell consists of carbonate of lime, and an organic substance called conchin; both are produced by the fold of skin known as the mantle, which is always adding to the shell, especially along the margin, as the animal grows bigger. The persistence of a free edge to which additions can be made as required obviates the necessity of that moulting which is characteristic of crabs and their allies. The intermittent or rhythmic growth of the molluscan shell is registered in the parallel lines already referred to and in a few cases the age has been estimated. It is certain that a mollusc may live for a good many years, a land-snail for three or four, a freshwater mussel for a dozen. One would like to know the age of those huge Tridacnas which are often used for holding holy water in churches. The shell may weigh more than a man can lift, and may measure more than two feet across. On his *Beagle* voyage Darwin was struck by these giant clams at Keeling Atoll, and noted that "if a man were to put his hand in, he would not, as long as the animal lived, be able to withdraw it."

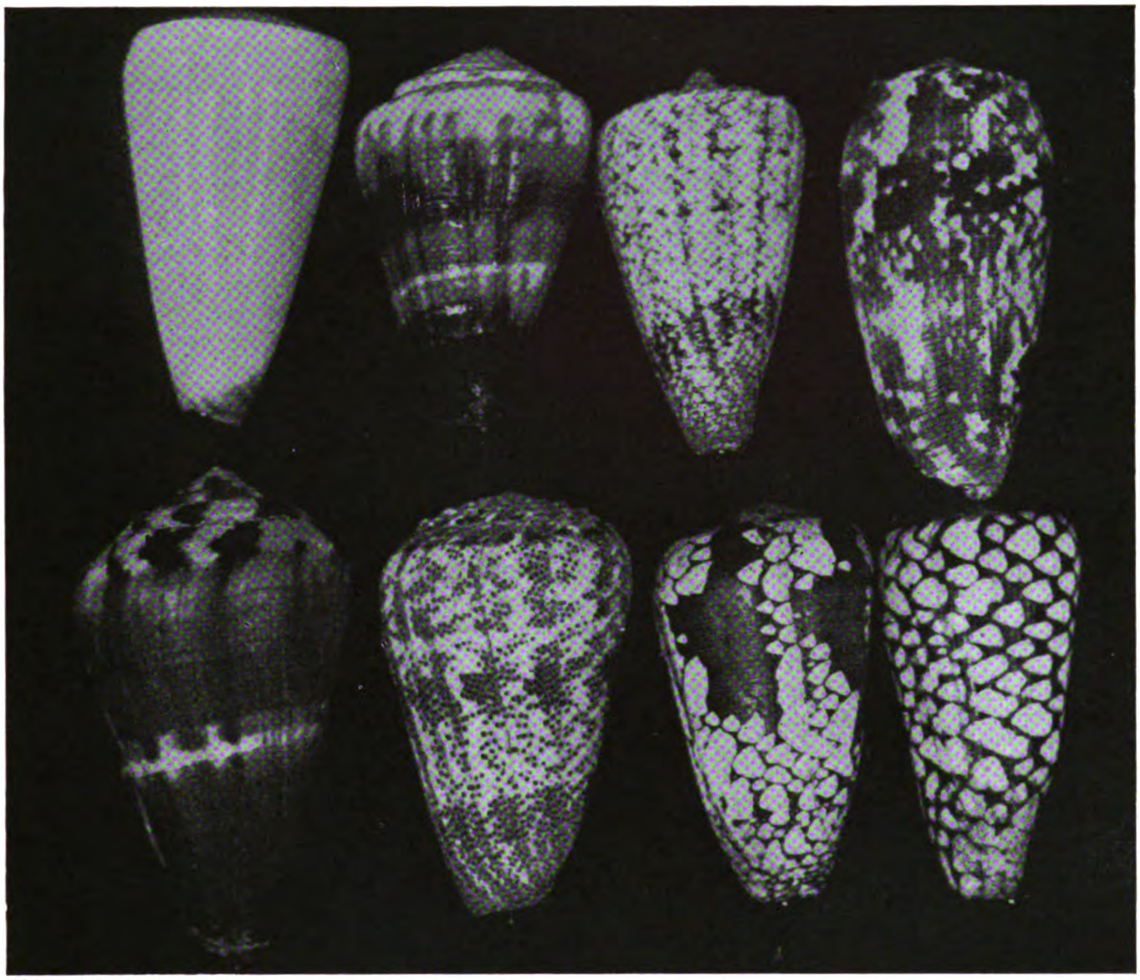


Photo: John J. Ward, F.E.S.

TROPICAL CONE-SHELLS.

The species of Cone-shell or Conus are numerous and variable like those of the Cowry. At the broad end some indication of the whorls may be seen, but they are overlapped by their successors and some may be absorbed. The mouth of the shell is long, narrow, and straight. The mouth of the animal has poisonous teeth in the rasping ribbon or radula, and the bite may be dangerous.

The valves are so massive that we suppose the animal must remain quite stationary, unable to do more than allow the shell to gape a little.

Many bivalve shells show three distinct layers. There is an outer organic layer of conchin, easily rubbed off. There is a prismatic layer with the lime arranged in prisms, recalling a similar architecture in the enamel of our teeth! Innermost and often very thick is the beautiful mother-of-pearl layer with delicate flat laminæ of lime and conchin, producing for physical reasons the well-known rainbow colours. When shells in shops show this iridescent layer on the external surface, this is due to the removal of the two outer layers. If a piece of the nacreous or mother-of-pearl layer is pounded into dust, you get, of course, just white chalk; all the witchery of colour is physical or structural. There is no pigment present in the mother-of-pearl. In the shells of most sea-snails there are three layers of platelets of lime, each layer with its own angle of slope, and the result is a porcelain-shell, often without much or any trace of mother-of-pearl. When the mouth of a Gastropod shows a deep-cut notch (for the reception of a breathing-tube), the creature, e.g., a whelk, is almost always a carnivore, and apt to be unpalatable. When the mouth of the shell is uninterrupted by any notch, as in the periwinkle, the animal is a vegetarian, and likely to be palatable.

In ancient times the cult of shells was widely spread, and there are lingering traces of it to-day. Shells were used as charms and amulets, and in later days as counters and coins. Most of all, they were symbols of love and sex, of life and fertility. It is surely a rebuke to us to find how remote from commonplaceness was the old-fashioned cult of shells. Ages ago men held the empty spiral conch to their ear to listen to the whisper of the god, just as our children do to catch the reverberation of the distant sea. What is this murmur of the shell? A little may be due, some authorities say, to the shell's intensifying of internal vibrations due to pulsing blood-vessel and tensely-strung muscle, but mainly it is due to the action of the shell as a sympathetic resonator, which picks out and exaggerates certain minute sounds from the surrounding medley (for "perfect silence" is rather a fiction). But not for the world would we disturb the fancy of the child who listens to the echo of the far-off sea, and in so doing is unconsciously echoing the practice of a far-off ancestry.

History of Guano

Dr. Robert Cushman Murphy has written a delightful book called "The Bird Islands of Peru" (1925), in which he discusses the natural history of guano, the most valuable of all fertilisers. As is well known, guano is formed on bird-smothered islands in dry regions in various seas, but the best guano is Peruvian. It is said to be thirty-three times as valuable as farmyard manure, and that is because the nitrogenous compounds of which it is mainly composed are in a state that makes them very valuable as food for the roots of plants. Though the word guano means dung, the material is chiefly the excretion of the birds' kidneys, which is got rid of in semi-solid form. It consists of urea and urates, phosphates and other salts of ammonia, and other compounds, such as guanin. The last is a waste product that we see, for instance, in the "green gland" or kidney of the lobster, and also as silvery spangles in the scales of many fishes. It is said not to be found in the fresh excretion of the birds, and is probably the result of the decomposition of uric acid. It may be noted that guano is valuable in inverse ratio to the atmospheric changes to which it is liable. But we must not go further into the chemical aspects of guano; it is enough for our present purpose to be clear that it is a complex mixture of highly nitrogenous waste products, and that it consists chiefly of the excretions filtered out by the kidneys, and only secondarily of the undigested residue of the food.

Along the shining sea coast of the Incas there is a profuse abundance of marine life, an abundance in great part due to the beneficent influence of a cool ocean current, which bears the name of Humboldt. Cooling always increases the density of the sea population (hence the success of northern fisheries), one reason being that the vital processes are less hurried than in the unrelieved tropical waters, and that more generations of a species are thus living at the same time. The thicker the living stock of the sea soup, the more abundant will be the fishes; and another step brings us in Peruvian waters to the great multitudes of barking and wailing sea-lions, and of birds "as numberless as snow-flakes in a March blizzard." There is said to be a larger sea-bird population here than in any other area of equal extent.

It is chiefly on the islands off the Peruvian coast that the finest guano accumulates, and the Chincha Islands are especially famous. The reasons for the crowding of the birds are in the main the same as those that account for the dense congregations seen, during the nesting season, on northern bird islands like Ailsa Craig, the Bass Rock, Handa and Fould, or on the low-lying islets appropriately called eider-holms. Whether by shelves and ledges of rock, or by an accessible surface with plenty of nest-building materials, the bird islands afford suitable breeding places; and the other indispensable feature is that there be good fishing within a convenient distance. Moreover, insulation tends to reduce the number of enemies, unless small mammals like rats manage to get a footing on the islands.

The most important guano-birds at present, in inverse order of value, are (1) the "blue-footed boobies" or camanays, tropical gannets belonging to the North American fauna; (2) the large yellow-headed pelicans or alcatraz (200,000 on the headquarters island!); (3) the variegated boobies or lancer gannets (piqueros in Spanish), the most abundant of all the guano-manufacturers; and (4) the white-breasted cormorants

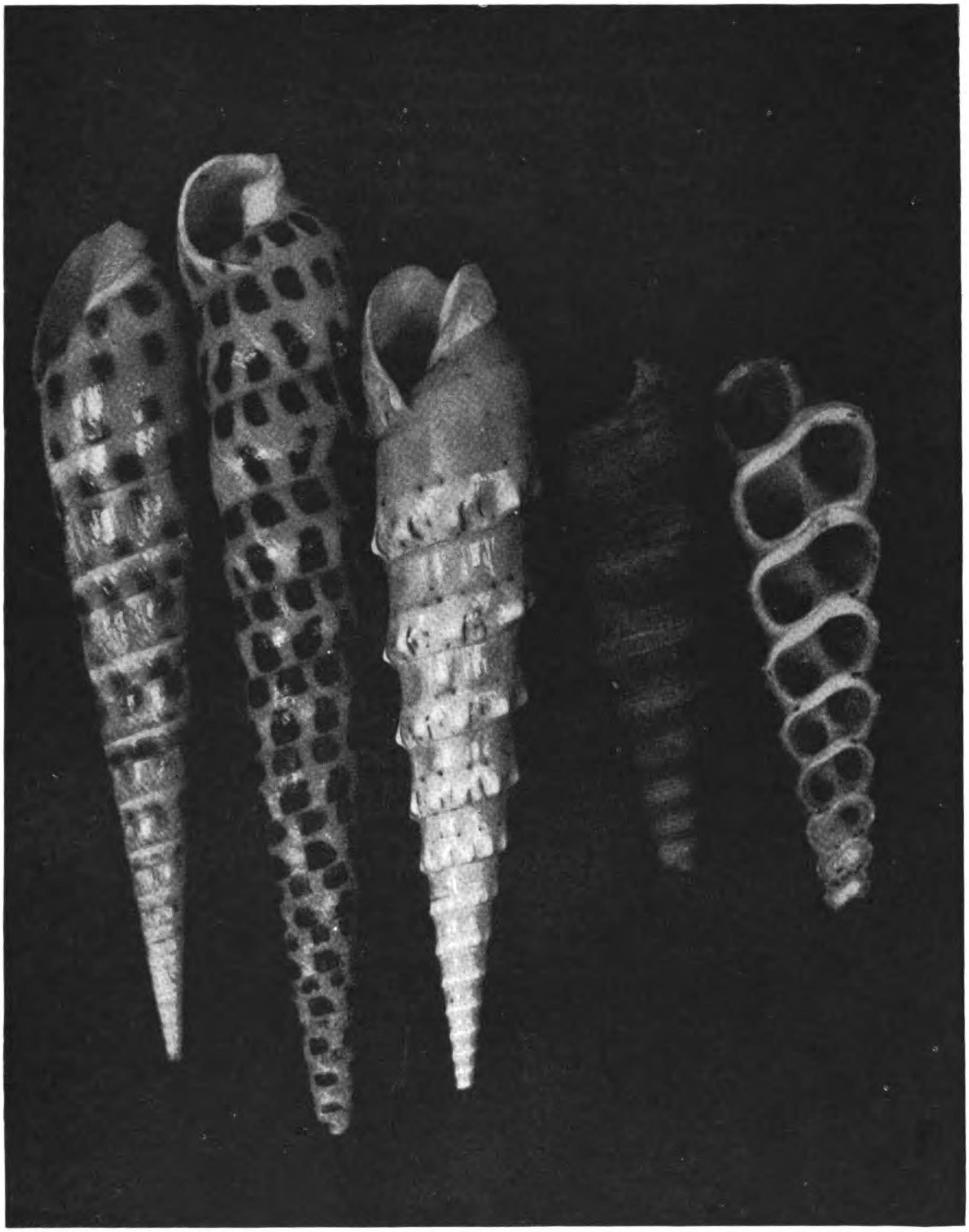


Photo: John J. Ward, F.E.S.

AUGER SHELLS (Terebra).

The shells of the genus Terebra are related to those of Conus, yet the spire is as long in the former as it is short in the latter. It will be understood that the young Gastropod lived in the small cup that is now the tip of the shell; as it grew it added whorl after whorl round a central pillar or columella, as the right-hand photograph of a section shows.

Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

THE RAZOR-SHELL RISING TO THE SURFACE.

The Razor-shell or Spout-fish, *Solen siliqua*, is a common bivalve mollusc that burrows in the sand about low-tide mark and further out. It is often hooked up for bait. When the animal is undisturbed, it protrudes two breathing-tubes at one of the gaping ends of the long somewhat razor-like shell. On the slightest disturbance, these are retracted and the animal goes deeper down.

Photo: F. Martin Duncan, F.R.M.S., F.Z.S.

RAZOR-SHELL STARTING TO MAKE A NEW BURROW.

The burrowing organ is the "foot," a muscular structure found in almost all bivalve molluscs, and usually serving for locomotion. The foot is protruded posteriorly, that is, at the end opposite that from which the two breathing-tubes emerge. It becomes stiff with inflowing blood and it is very muscular; it works like a probing finger into the sand and pulls the animal in.

or guanayes, peculiar, like the lancer gannet, to the Humboldt Current, but of Antarctic origin.

The piquero or lancer gannet is a bird that incites our admiration. It outdoes our own Solan Goose as a spectacular plunger. Dr. Frank M. Chapman, of the American Museum of Natural History, speaks of the impossibility of picturing a skyful of boobies pouring downward into the sea. " It was a curtain of darts, a barrage of birds. The water below became a mass of foam, from which, if one watched closely, hundreds of dark forms took wing at a low angle to return to the animated throng above, and dive again," or else, of course, sail home heavy with booty. Dr. Chapman describes the extraordinary plunging of a flock of five hundred to a thousand boobies, which, in making for a distant goal, happened to fly over a school of fish. " Instantly and as one individual every booby in the flock plunged downward, and in a twinkling the air, which had been filled with rapidly flying birds, was left without a feather!" It is difficult to understand how the plunging birds in a barrage avoid impaling their comrades who are emerging from the water. But there are probably many hidden tragedies.

Which is the most valuable bird in the world? This is one of Dr. Murphy's questions, but it is unanswerable until we have a definition of " value," which the political economists have not succeeded in giving. Is it the barndoor fowl or the high-flying stork, the insectivorous swallow, or the orchid-fertilising humming-bird; is it the red grouse on the high moor or the skylark in the meadow; is it the ostrich with its plumes which it is lawful to wear, or the Bird of Paradise, whose forbidden plumage is worth ten times its weight in gold? Dr. Murphy answers: " Figuring in dollars and cents, and with reference to effect upon human life and human geography, I beg to present my candidate for the post of king among avian benefactors—the Peruvian cormorant or guanay." In other words, the most valuable bird in the world is the bird that makes most guano, for guano spells bread, just as guanay spells anchovy, and anchovy copepod, and copepod infusorian and diatom. For so the world goes round.

The guanayes are cormorants of Antarctic origin that have established themselves in vast colonies along the islands of Humboldt's Current. Unlike ordinary cormorants, they hunt by sight and from the air, plunging on surface-swimming fishes, such as anchovies. They leave their islands in small scouting parties, but when a great school has been discovered there is soon a vast congregation. The birds hang like a black cloud over the sea, and when they shift their quarters, flying low, they form a continuous dark river, which may take four or five hours to pass a given point. In a report to the President of Peru, Dr. H. O. Forbes, a well-known British naturalist, estimated the cormorant population of Central Chincha Island at 5,600,000, and

Photo: Reproduced from " Bird Islands of Peru," Robert Cushman Murphy, by courtesy of the publishers Messrs. G. P. Putnam's Sons.

GUANAYES ON THEIR TWELVE-POUND NESTS (*Phalacrocorax bougainvillei*).

The Guanay is a white-breasted cormorant, peculiar to the Humboldt Current, but with Antarctic affinities. It is regarded by some as " the most valuable bird in the world," because it contributes so enormously to the making of Peruvian guano.

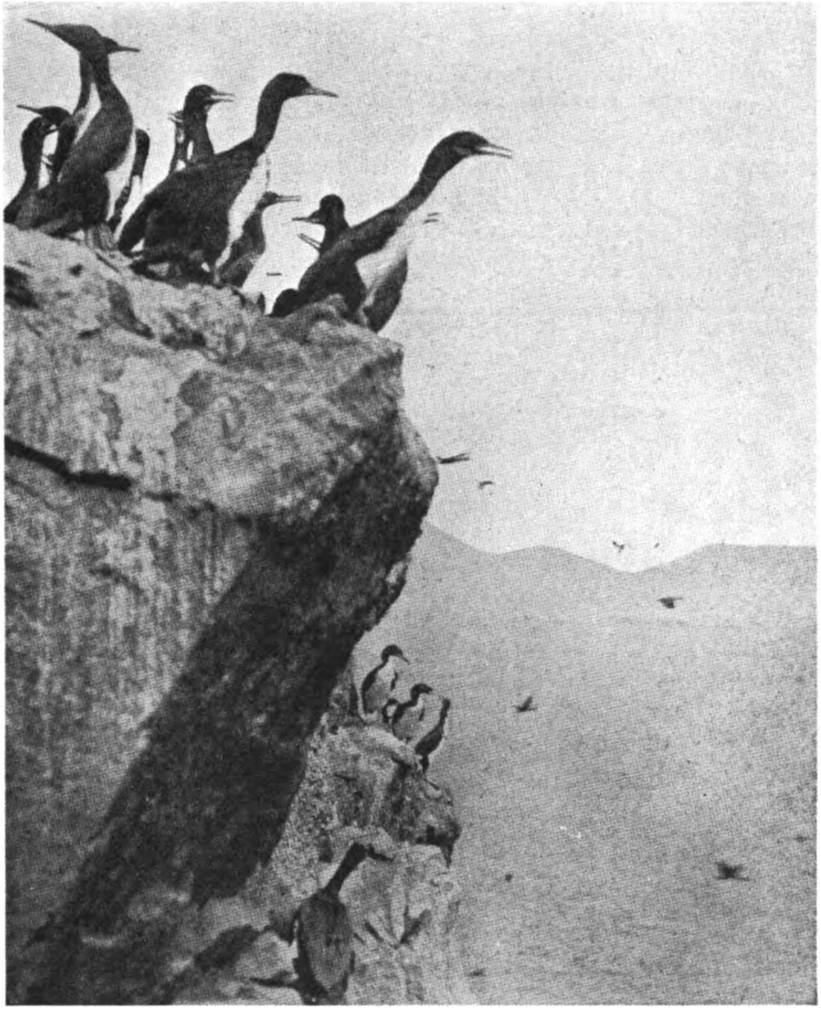


Photo: Reproduced from "Bird Islands of Peru," Robert Cushman Murphy, by courtesy of the publishers, Messrs. G. P. Putnam's Sons.

GUANAYES AT THE BRINK OF PESCADORES ISLAND—THE MAINLAND OF PERU IN THE DISTANCE.

While the Guanay is a true cormorant it is in many ways remarkable. It "hawks ' its food by sight from the air before it descends; it lives altogether on surface fishes; and it is gregarious in its fishing.

calculated that it would require 1,000 tons of fish per day to keep this single colony alive. In the crop and stomach of one cormorant Dr. Murphy found the remains of no less than seventy-six anchovies, four or five inches in length; so there is no reason to doubt that the 1,000 tons per day would be duly forthcoming.

We get from Dr. Murphy some lively impressions of the life of the guanayes on the guano islands. They always come home at night and insist on getting in, though all the bedrooms are occupied. The hum of their wings is "like the effect of an overdose of quinine upon the ears"; their voices make "an outlandish and never-to-be-forgotten babel." But they have some pretty ways, these guano-makers! How they bend and bow, tremble and pose, in their courtship, sometimes five assiduous suitors around one crouching hen. How vigorously they wash themselves, the great companies at their toilet making a noise like the crashing of waves on a rocky shore. "Whenever a man, sitting perfectly still, begins to talk to the guanayes in a loud voice a silence falls over all the audience within hearing. Their mumbles and grunts die away, and they listen for a while as if in amazement." One thinks of Anatole France's "Penguins," which the guanayes resemble in their erect walk. It should be noted that, unlike their Antarctic relatives, the guanayes are non-seasonal in their nesting, though an individual pair has not more than two broods in the year. There is thus an abundant production of guano-producers; and one is glad to know that under the modern well-organised system of rotation there is no reason that there should be any end to turning the dust of the sea into the staff of life.

Photo: Reproduced from "Bird Islands of Peru," Robert Cushman Murphy, by courtesy of the publishers, Messrs. G. P. Putnam's Sons.

GUANO BIRDS ON LOBOS DE TIERRA, ONE OF THE PERUVIAN ISLANDS.

This remarkable photograph by Dr. Murphy shows the step-like nests of the guanayes covering the lower hillside, half-grown pelican chicks in the foreground, and adult pelicans along the crest.

LXII
CAVE ANIMALS

THERE is a fascination in exploring a cave, especially when it is tenanted. If one does not object to mud and darkness and narrow passages, the touch of silent wings on one's face, the patter of unseen feet, contact with slimy creatures on the cold walls, mysterious reverberating sounds at rare intervals, knocking one's head against the roof, stumbling into a pool of water and losing one's last torch, the exploration of a cave is a joy—a fearful joy. Like going down a mine for the first time, it is a visit to a new world. The darkness, the silence, the quiet air—what a contrast to the world outside that seems so far away. What a disclosure when several torches are lit—the subterranean architecture, the domes and arches and pillars, the hanging stalactites (" limestone icicles ") and the uprising stalagmites that tell us if we break them how old they are. For many stalactites show annual rings like the stem of a sawn tree, the reason for this being that there is a stoppage of growth in the dry season, or that more air-dust settles on the growing surface during the summer. It is also possible to calculate the age of the stalactite by estimating the rate of drip and the amount of dissolved lime in each drop. Thus Dr. Vernon C. Allison calculates that a gigantic stalagmite, known as the " Pillar of the Constitution," in Wyandotte Cave, Indiana, which is seventy-one feet in circumference and about thirty feet in height, has an age of 30,500 years.

Cave-Dwellers.

Besides architecture there is sometimes extraordinary colouring disclosed by the torchlight, strange weatherings and rustings, and gleaming reflections from crystal mirrors in the rock. In sea-caves, into which the tide rushes and splashes high, there is often a rich colouring due to the encrustations of calcareous Algæ, which fit the rock like a coat of paint. But we shall keep to inland caves.

Another attraction is to be found in searching for traces of the living tenants that have effaced themselves before the torch. The spider's web in that niche shows that there are many flying insects in the cave; there on the mud are the tiny footprints of a mouse; and there on the rock are the droppings of bats. One also has the excitement of searching in the floor of the cave ever so carefully with a trowel for relics of human and other troglodytes (cave-dwellers) that were tenants long ago. Sometimes there is the satisfaction of being able to decipher from the different layers of bones and other vestiges in the well-trodden floor the sequence of bygone inhabitants. Occasionally there is an indication of where a fire was lit—perhaps in prehistoric times. If we are very lucky we may discover a non-modern writing or drawing on the wall.

In *dark* caves—the only thoroughgoing caves—there can be no green plants, though sometimes near the entrance there are a few shade-lovers like the Golden Saxifrage and the Moschatel, some lichens which are half fungus, and in rare cases a moss (Schistonema) with glistening spots that look like eyes, and seem to act as little lenses, making the most of the scanty rays of light. Inside the cave the only plants are moulds and other fungi.

But let us call the animal roll, which is very considerable. There are various Infusorians and amœba-like unicellulars in the pools, and elegant wheel animalcules or Rotifers with great complexity in small bulk. A Rotifer may have a thousand cells, a food-canal and other organs, and yet be able to pass through the eye of a needle! Wherever decaying débris has been brought in by a streamlet or has accumulated from droppings of bats there are delicate thread-worms; and there are other kinds of worms including a kind of leech (Dina)—wan and blind. The largest part of the cave-population, as far as numbers go, is made up of jointed-footed animals—small crustaceans in the water and wood-lice in the crevices of the rocks, numerous centipedes and insects, spiders and mites.

But most of them are very minute. On a different tack are various dwarfish slugs and snails, which feed chiefly on fungi.

. Among backboned animals there are numerous fishes, with eyes at all levels of degeneracy, and there are about half a dozen newts and salamanders. So far as we know, there are no cave-reptiles. But it seems a little pedantic not to include such a cave-lover as the oil-bird (Steatornis) of South America and Trinidad. This curious bird is a distant relative of the insectivorous night-jar, but it feeds on fruits, for which it searches in the twilight. A large cheese-like nest of heterogeneous spongy materials is built on ledges or in holes in caves, and the young birds are famous for their extreme fatness. When about a fortnight old they are quilted with yellow grease, out of which the natives make a colourless oil, used for lighting and cooking. The plump young birds are regarded as a delicacy, in spite of their cockroach scent. We call the oil-bird or guácharo a cave-bird, just as we call bats cave-mammals, for they stay in the caves all the day. " The flight is noiseless, and occasionally high in the air. Visitors to the breeding caves are suddenly surrounded by a circling crowd of Oil-birds uttering loud croaking or rasping cries, the effect being enhanced by the rush of multitudinous wings. A more plaintive note is uttered by individuals at rest " (A. H. Evans, Cambridge Natural History, Vol. IX, 1899, p. 419).

In many comparatively recent caves, dating geologically from after the worst of the Ice-Ages was over, there are remains of big mammals, like the Cave-lion, the Cave-bear, the Cave-hyæna, and so on ; but these were not cave-animals in the true sense. They merely used the entrance of the cave as a shelter for the night or as a nursery for the young. The only true cave-mammals are the bats, which we shall deal with separately ; and a few mice may be added.

It seems desirable to draw a distinction between permanent cave-dwellers, sometimes called " troglobions " (*troglos*, a cave ; and *bion*, a living inmate), and those that go out and in ; the " troglophils " (*troglos*, a cave ; and *phil*, fond of). The troglobions are permanent residents, at home in the cave, such as the blind Dalmatian newt called Proteus. The troglophils are temporary tenants, for part of the twenty-four hours—as in the case of bats ; or for part of the year, as is the case with one of the owls

Photo : E. J. Manly.

THE OIL-BIRD (*Steatornis caripensis*).

This quaint bird, also called Guácharo, is somewhat intermediate between the owls and the night-jars. It occurs in Venezuela, Colombia, Ecuador, Peru, Guiana, and Trinidad, living in seaside or mountain caves, coming out only at night, and flying noiselessly in search of fruit. Its body is very fat and yields oil suited for lighting and cooking purposes.

(Scoliopteryx) which spends most of the winter in caves. But this distinction between permanent and temporary tenants must not be pushed too hard. Thus Proteus, which is as thoroughgoing a cave-animal as one could find, is occasionally flooded out into the Lake of Zirknitz, where, we believe, it manages to survive. On the other hand, it seems desirable to keep the troglobions and troglophils separate from casual visitors to the caves, which have wandered in, or fallen in, or been carried in, yet have not in any way settled down. They may be compared to some of the animals that have been reported from coal pits—a list of considerable length. In his "Animal Life in Scotland" (1920, p. 416), Dr. James Ritchie records thirteen different kinds of animals from a pit in the Midlothian Coal Field. The list included sparrows, rats, and mice, which may be called casual, while the Cave Spider (*Lessertia dentichelis*) was thoroughly at home and "fared sumptuously upon the insects that frequented the workings." In speaking of "casual visitors," one must of course recognise that while their entrance may be called fortuitous, yet they would not have survived at all unless they possessed certain qualities which enabled them to adjust themselves to the peculiar conditions of cave-life. It is time to turn to these conditions.

What is involved in a thoroughgoing cave? Absolute darkness, a uniform temperature, corresponding to the annual average for the outside world at that particular place, a very humid atmosphere (there are no permanent tenants in dry grottos), and an absence of air-currents. The cave is a dark, damp, still place. For permanent tenants the cave is more or less of a prison; they cannot readily return to the open world even if they would, and cases like the washing out of the Proteus are rare. The troglodytes are isolated, and unless the cave is very large there must be a good deal of *in-breeding*, that is to say, pairing within a narrow range. This may throw light on the very considerable length of the list of cavernicolous species. For when variations crop up in conditions of isolation, whether on an island or in a cave, it is easier for them to become compacted into a uniform true-breeding species. Let us recall cases like the Orkney Vale and the resident St. Kilda wren. There are many similar instances among the cave-dwellers. And here it may be noted that cave-animals are either the direct descendants of ancestors that came in or were carried in from the open world outside; or else they are new forms that have arisen in the cave from the variations of previously established troglodytes. It is interesting to find that a cave-animal sometimes shows great variability in regard to its eyes; that is to say, these organs are fluctuating; and if it should be an advantage to be blind in the darkness, there is ample material from which individuals changing in the direction of blindness might be sifted out.

How are cave-animals suited to the cave? One of their features is sensitiveness to touch, obviously of great importance to dwellers in darkness. When we find a crustacean or an insect with very long feelers (or antennæ), long when compared with those of relatives that have remained out of doors, we must call the lengthening out a special fitness or adaptation. There are some little sandhopper-like cave-animals that have feelers longer than their body, and there is a locust-like insect in the Mexican grotto of Cacahuamilpa that has a body length of about two-fifths of an inch and a feeler length of nearly two inches! And besides feelers, there are other tactile structures that are strongly developed in cave-animals.

Important also is the sensitiveness to moisture, for this keeps the cave-animals from straying into unprofitable places. Few cave-animals can stand drought. Even those that cannot see in the strict sense—that cannot form an image, are sensitive to light and shade, and are constitutionally disposed to move away from the light. This "negative heliotropism," as it is learnedly called, is comparable to the obligation that makes a young root grow *down* and a young shoot *up*, and it will tend to keep the troglodytes from wandering out of the cave and even from following the streamlet as it trickles towards the light. Another interesting feature is sensitiveness to currents of air. Just as there are some people who cannot stand the least draught, so is it with cave-animals. They like a very quiet life. There is a cave-beetle called Antisphodrus which shows itself indifferent to changes of light, but is so sensitive to the least breath of air that it moves away if you whisper its sibilant name.

Specially drawn for this work by Warwick Reynolds, R.S.W.

BRITISH BATS.

The one shown largest is the small Pipistrelle. Hanging to the branch is the always recognisable Long-eared Bat; and it is also shown in flight, below the Pipistrelle. To the left below is the large Noctule. These are three typical British bats. Two of the drawings show very well the triangular skin-basket or inter-femoral membrane.

In thinking of the use of all this exquisite sensitiveness, we must remember that the cave-animals have to find their food and avoid their enemies in complete darkness. It is therefore very important that they should be sensitive to touch and movements and odours. The food consists of other animals, or of their remains, or of the droppings of bats, or of débris washed in from without, or of moulds and other fungoid growths. In some caves there is an abundance of food, and there are crowds of crustaceans, insects, mites and snails; but in the majority of cave-retreats the cupboard is very bare. Many cave-animals require to be very alert if they are to get enough to eat and if they are to eat without being eaten.

Many cave-animals are quite blind and many have dwindling eyes. In a way this may be ranked as a fitness, for eyes are of no use to animals living in complete darkness. If so, it is profitable that they should disappear, since a useless organ is a waste. Moreover, an eye in complete darkness may be a weak spot, since it is liable to be injured.

It is very natural to think of blind cave-animals becoming blind because of the darkness, but perhaps this is too simple a theory, especially in view of the fact that there are many cave-animals that are *not* blind. We shall discuss the question in a special section on "Blind Animals."

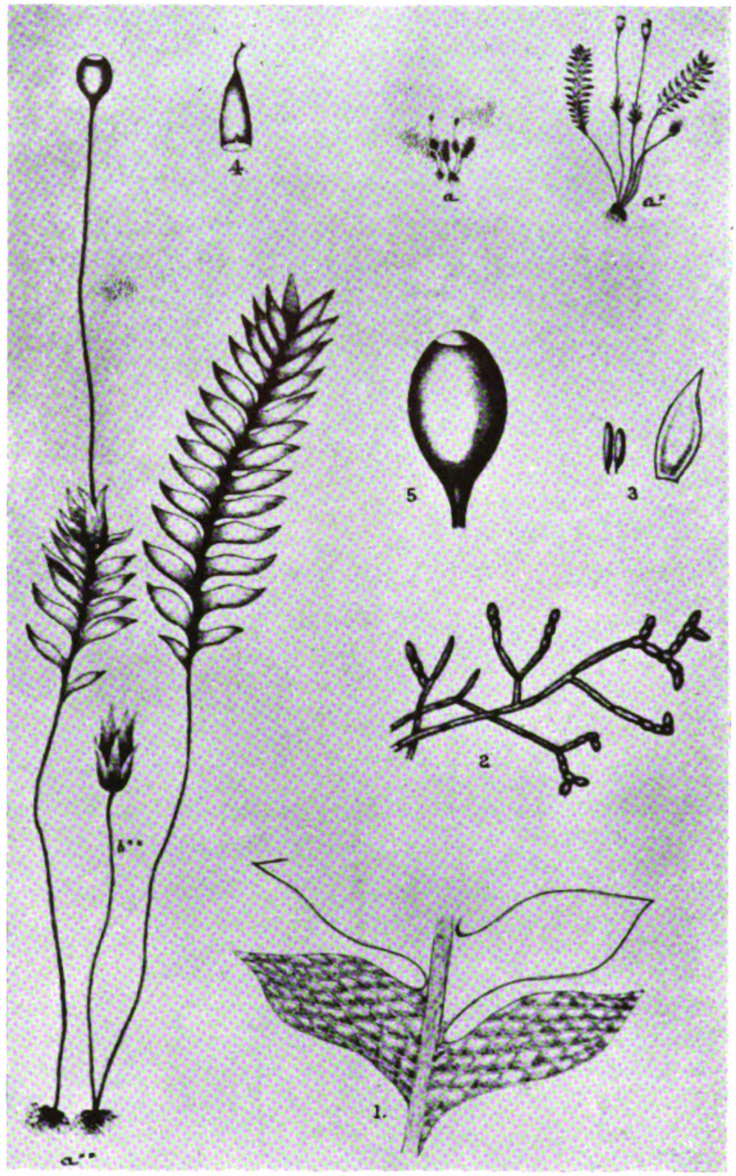


Photo: Reproduced from "The British Moss-Flora," by R. Braithwaite, M.D., F.L.S.

A CAVE MOSS (*Schistostega osmundacea*).

This "luminous moss" has somewhat lens-like cells on the threadwork or protonema (2) from which the plant starts; these focus and then reflect the scant rays of light. *a*, the full-grown plant; *a** and *a***, the same magnified, showing the spore-capsule borne on a delicate stalk; *b***, the male moss-plant magnified, with the reproductive organs at the apex; 1, the leaves much enlarged; 2, the initial threadwork or protonema that grows from a spore; 3, the male organs and a protective bract; 4, the cap or calyptra of the spore-capsule (5).

There are various characteristics of Troglodytes that can hardly be called fitnesses. Thus many of the dwellers in darkness are like Proteus in being colourless, translucent, or milk-white, which probably means that pigment sometimes fails to develop in the absence of the light-stimulus. When small freshwater crustaceans, such as "screws" (Gammarus) and "water-slaters" (Asellus) are kept for a long time in total darkness, they become very pale, and if the experiment is continued for years, generations are born with almost no pigment. Conversely, translucent specimens from the caves become brownish if they are kept in the light.

Photo: A. W. Dennis.

THE GOLDEN SAXIFRAGE (*Chrysosplenium oppositifolium*).

This is a common British shade-plant, frequenting moist places, such as the rocks beside waterfalls. There is an underground stem which gives off above-ground shoots with yellowish-green leaves and clusters of minute greenish flowers without petals.

But we do not know that there is any advantage in being pale or translucent in a cave.

Another feature of many cave-animals is the delicacy of the skin; and here again the difficult question arises: Are these animals soft-skinned because they and their forbears lived in the stillness and dampness of the cave, or did their ancestors take to the caves because they were thin-skinned, and unequal to the more strenuous life in the open? Another common feature, especially of those that do not live in the water, is small size. Proteus is a giant, ten inches long, but most cave-animals are pygmies. What is called the giant cave-amphipod, like an aquatic sandhopper, is only two inches long!

We read of the Cave of Adullam, where King David took refuge, that "every one that was in distress, and every one that was in debt, and every one that was discontented" gathered there; but it seems to be a little different with animals and their caves. For the men that found a rendezvous at Adullam were fighting men with a grievance, whereas the animals that take refuge in caves are, we suspect, animals with a weakness. They have slunk shyly away from the keen struggle for existence in the outer world, seeking a quiet life, even if it means short commons. They are not weak because they become Troglodytes; they became Troglodytes because they were weak. The cave is a retreat—an asylum.

The Story of Proteus.

One of the most famous of cave-dwellers is the "Olm" or Proteus, a newt of sorts, a dweller in darkness in the underground waters of Carinthia, Carniola, and Dalmatia. It is known from over forty localities, mostly caves with slow-flowing streams. When the streams are low, the olms are often found in stagnant pools with a muddy bottom, but their preference is for flowing water. When the streams are swollen, the olms are occasionally carried outside the cave into the light, which they do not seem to enjoy. One of the earliest

records (1761) of Proteus was from the Lake of Zirknitz, into which it had been swept by a flood. But we must certainly think of the animal as a typical cave-dweller, a true troglodyte, not at home in the light. It is nocturnal all its life and all the twenty-four hours, and though it can wriggle on wet mud, it prefers to keep to the water. The temperature of its haunts is low and uniform, about fifty degrees Fahrenheit.

Picture a slender, blind, newt-like animal, towards a foot in length, with smooth, flesh-coloured skin. There are sometimes hints of spots, but the most marked touch of colour is where the red blood shines vividly through the three pairs of gills. These are usually branched or tufted. The head is elongated and obtuse in front, a little suggestive of a pike's. Proteus is very weak in the legs, which must be regarded as in process of degeneration. They are not strong enough nor long enough to support the body; the fore pair have only three fingers, the hind pair only two toes. The swimming is effected by lateral undulations of the tail, which is flattened from side to side, in contrast to the cylindrical trunk of the body.

Museum specimens of Proteus look very white and wan, except at the gills, but it is of some importance, as we shall see, to notice that the living animals show considerable variability. There are hints of yellow, reddish and even violet in the ground colour, and of yellow, grey and reddish in the spots. This probably depends mainly on the surroundings, especially on the intensity of the darkness, for there is no doubt that even faint light induces colouring or pigmentation. Similarly, while we may fairly speak of the olm as blind, meaning that the eyes are degenerate and do not reach the surface, it is of interest to notice that they can sometimes be seen as darkish points shining through the skin, and that they are more marked in the young than in the adults.

Very little is known of the home life of Proteus, for a dark cave is not suitable for zoological

Photo: A. W. Dennis.

MOSCHATEL (*Adoxa moschatellina*).

A beautiful little flower found in North Temperate shady woods. It has minute flowers in a greenish cluster at the end of a slender upright shoot, well seen to the left of the photograph. These are visited by small flies, attracted by the musky smell.

observations. Indeed, the chief haunts are probably inaccessible, since no larvæ, or even youngsters, are ever found. Fortunately the animals are patient of captivity, and up to an uncertain limit we can argue from the known to the unknown. Thus it is safe to say that they breathe in some measure by their lungs as well as by their gills; that they must have well-aërated water; that the adults are put about by illumination, for a time at least; that they thrive best when the temperature of the water is low and uniform; that in captivity they feed on water-fleas (small crustaceans) like Daphnia and Cyclops, and on little river-worms like Tubifex. It may be mentioned that, in spite of their blindness, they can find threads of raw flesh held out towards them in the water. An examination of the stomach-contents of specimens of Proteus from the caves shows that in natural conditions they feed in part on small crustaceans (such as a cave-amphipod called *Niphargus stygius*) and on small water-worms. Of course there are no green plants in the subterranean waters, unless they are being carried past by the stream.

It is possible to get olms to breed in captivity, and thereby hangs a rather interesting tale. In the early spring the male sometimes shows a heightening of the caudal fringe, and the female, plumper than usual, shows eggs shining through the translucent skin. The eggs are fastened singly to the under side of projecting stones in the water, and a female may produce twelve to fifty-six altogether. There seems to be no certainty about the mode of fertilisation, but it must be internal, not as in the frog where the eggs are fertilised as they are laid. Each egg is about a sixth of an inch in diameter, but it is surrounded by an envelope and then by a zone of transparent jelly, as in frog's spawn, so that the diameter rises to nearly half an inch. In about ninety days the larvæ emerge, nearly an inch long, miniatures of their parents except in a few particulars. Thus there is a delicate unpaired fin that begins on the posterior part of the trunk, and is continued round the tail; the diminutive hind-legs have not yet attained to having even two toes; the eyes are distinctly visible as dark spots shining through the skin. During the development, which goes on in darkness, the embryo is quite without pigment, but when the newly hatched larvæ are brought into the light to be studied they quickly put on numerous minute spots of a brownish colour. So much then for Proteus as an egg-laying animal, but this is not the whole story.

In the Experimental Station at Vienna, Dr. Paul Kammerer kept olms in a very suitable place, a deep hole sixteen feet below the surface of the ground, constantly supplied with uniformly cold and fresh water. In these conditions the olms brought forth living larvæ instead of laying eggs! In our clumsy words they were viviparous, not oviparous. The strong probability is that the laying of eggs is an unusual method of multiplication for the olms, and brought about by lack of uniform coolness in the water. One cannot at present be quite sure, but it is likely that viviparous birth is the rule in the caves. In giving birth to the living larvæ the female is suspended at the surface of the water with the anterior and posterior parts of the body curved downwards. The birth is usually in October. If the few observations that have been made form a broad enough basis, we may say that the viviparous method of giving birth shows an interesting economising of reproduction, for there are usually only two larvæ born at one time. It is plain that the more telescoping there is of the early stages in an animal's life-history, the more are the chances of death reduced, and the smaller the family may become without passing the limit of safety.

Proteus is in many ways of great biological interest, especially perhaps in showing the interaction of "Nature and Nurture." By "nature" is meant what is inborn—the inheritance; "nurture" includes all the influences of surroundings, food, and habits. Normally, in its dark haunts, it is almost pigmentless; but it has not lost the hereditary factor for pigmentation. For when it is brought into a lighted laboratory it soon becomes spotty—its skin is sensitive like a photographic plate—and in several months it may be quite black. If it be returned to the darkness, it slowly loses its pigmentation; and if the blanched specimen be brought back to the light it becomes dark again. Light is an external "nurture" factor necessary for the expression of the internal factor for pigmentation which still remains part of the hereditary nature.

In the caves the eye is arrested in its development; it begins well, but retrogresses; it lies

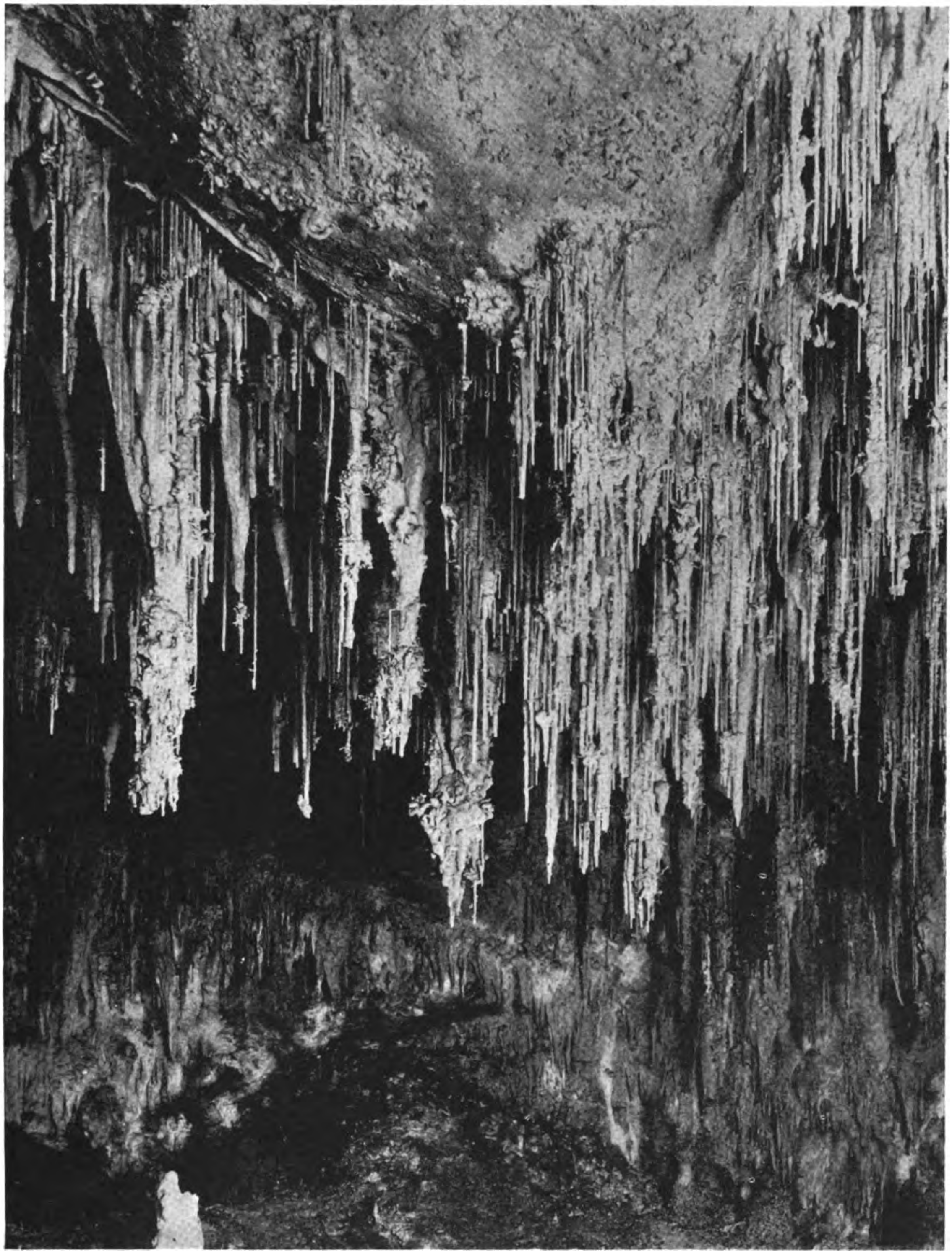


Photo: Ray V. Davis, reproduced by courtesy of the "Wide World Magazine."

PENDENT STALACTITES OF THE "KING'S PALACE" IN THE CARLSBAD CAVERN, NEW MEXICO.

A cave like this seems to have been formed by the dissolving of the limestone by the percolation of rain-water charged with acid. This acid was probably derived from decaying vegetable matter on the surface. Stalactites and stalagmites are due to the evaporation of the water containing the dissolved lime. The stalactite grows from the roof downwards, the stalagmite rises up from the floor of the cave.

Photo: Ray V. Davis, reproduced by courtesy of the "Wide World Magazine.'

CARLSBAD CAVE IN NEW MEXICO.

This is one of the largest caves in the world, and is famous for the beauty of the colouring, the variety of pendent stalactites and uprising stalagmites, and the spaciousness of the many rooms. What is called the "Big Room" is half a mile long and about a thousand feet wide. The photograph shows what are called the "Twin Domes," like columns of an Egyptian temple.

about a hundredth of an inch below the thickened skin. The creature is blind. But Kammerer has shown that if the newly hatched larvæ are reared in red light, the eye develops into a seeing eye. After five years of red light, or white light periodically interrupted by red illumination, the olms showed eyes with a transparent cornea, an iris, a large lens, a retina with rods and cones, and so on—in short, almost normal eyes. The reason why white light alone will not serve is that, unlike red light, it brings about the development of dark pigment in the skin over the eye, and this stops further progress. We could not have a better instance of the way in which " nurture " helps or hinders " nature " : in the caves the olms are pale and blind, in the sunlit laboratory they become black, under a red lamp they develop eyes that can see.

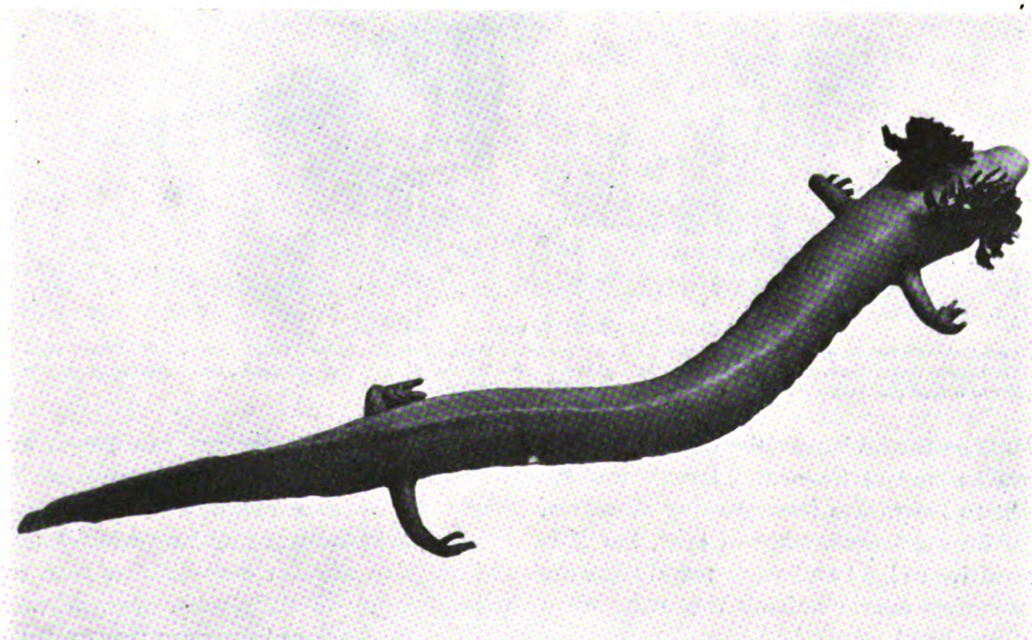


Photo: E. J. Manly.

THE OLM (*Proteus anguinus*).

This blind newt is confined to the subterranean waters of Carniola, Carinthia, and Dalmatia. It may reach a length of about a foot, white in colour except when slightly flushed with the red blood shining through. The three pairs of gills are also red with blood. In an illumined aquarium it soon puts on pigment; and a young one reared under red light may have the hidden eye exposed and developed into a seeing eye.

Another blind newt called Typhlomolge, a near relative of Proteus, occurs in subterranean caves in Texas. This is very interesting, for the two, though very far apart geographically, are so near one another in structure that we must think of them as having a common ancestor, probably like the Mud-puppy (Necturus) of North America. It is striking that these second cousins should have independently become cave-animals in homes so far apart as Dalmatia and Texas. The Texas cave-newt is white and blind like Proteus, and it is only known from specimens that came up with the water from an Artesian well 188 feet deep. They refused to feed in captivity and soon died.

Thinking of caves and other dark places leads us naturally to consider blind animals in general. Are there many of them? Where do they live? How do they hold their own? In the late Mr. E. H. Aitken's delightful book, called " The Five Windows of the Soul," there is a wise sentence at the beginning of the chapter on Sight: " Before Life had a window to open to Light, Light was long knocking for entrance into Life." Thus plants have no eyes in the true meaning of the word, yet Sir Jagadis Chunder Bose has shown that a tree is sensitive to a passing cloud; and the most important process in the world (photosynthesis) depends on the utilisation of the light by the green leaf. Many a simple animal without any trace of eyes draws towards the light, and

Blind Animals.

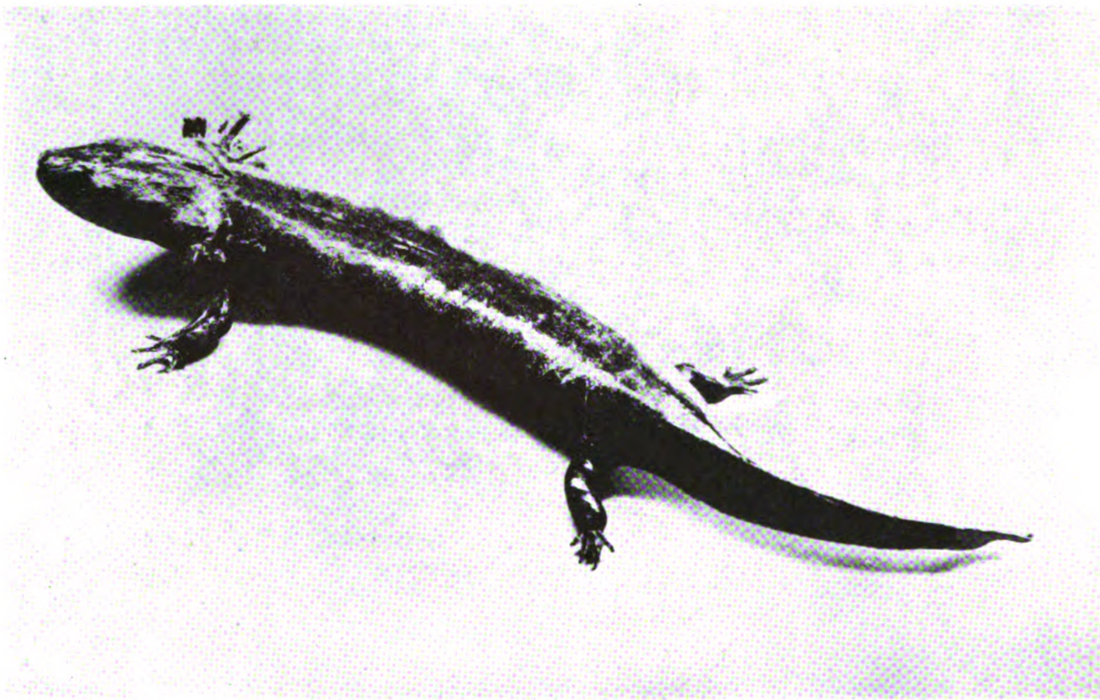


Photo: E. J. Manly.

THE MUD-PUPPY (Necturus or Menobranchus).

This newt, about a foot long, belongs to the same family as the Olm or Proteus. It lives in lakes in the eastern half of the United States, lying at the bottom during the day, often hidden among water-plants, but hunting at night for crustaceans, insects, worms, and even frogs. Three pairs of fringed gills persist throughout life, whereas they disappear in ordinary newts.

the plants on the table near the window have to be turned round at frequent intervals towards the light to keep them from growing all askew. The earthworm has no trace of eyes, but it is very sensitive to light and shade; and there are various eyeless marine animals that react when we put our hand gently between them and the sun. There is a long inclined plane between the simple eye of a jellyfish and the wonderfully perfect eye of a gull; and it seems that the function of the eye was primarily to discriminate between light and shade, secondly to detect movements of adjacent objects, and only thirdly to form images and distinguish colours. Keeping the word eyeless for relatively simple animals which have no special windows for light, we wish to think over blind animals in which the eyes are degenerate or altogether suppressed in adult life.

As we have seen, some degree of blindness is common among cave-animals, e.g., the Olm or Proteus of the Dalmatian subterranean streams, the American Blind Newt (Typhlomolge), many fishes, a blind prawn, and a blind crayfish, blind beetles, blind spiders, and so on through a long list. There are many facts that give us food for reflection. Thus there are cases, e.g., among cave-fishes and cave-salamanders, where forms with normal eyes and forms with very degenerate eyes occur in similar conditions, which raises the old question whether cave-dwellers took to the caves because of their weak eyes, or whether the poorly developed eyes are due to disuse in darkness, or whether seeing forms got washed in by accident and those more sensitive to faint gleams found their way out, generation after generation, while those that were inclined to vary in the direction of dull vision or blindness remained.

Then there is the fact that the young stages of the cave-animals sometimes have eyes showing much less degeneration than in the adults. This raises the question whether the final going-back of the eye is not in part impressed upon the individual as the result of a lifetime of disuse and lack of stimulus. It may be that blindness is sometimes a change impressed on the individual dweller in darkness, and we know that a goldfish kept in the dark for three years became quite blind, losing the rods and cones of its retina.

A second group of blind animals is that of the

more or less blind burrowers. The mole is a good example. Its minute eyes are hidden among the hair, and are what one might call half-finished. Aristotle was right, as usual, in saying that the mole's eye has all the parts of our eye except the lids; but if it can form an image it must be a blurred one. There is a little aperture in the skin over the eye in the Common Mole, but this is closed in Savi's Mole, found in some parts of the South of Europe, which was perhaps the species that Aristotle examined over two thousand years ago. Mr. Barrett-Hamilton points out in his masterly "History of British Mammals" that the conflicting statements made by careful naturalists in regard to the mole's power of vision may be due to the fact that the eyesight is variable. Towards the southern limit of the mole's distribution in France, the eyes are not infrequently concealed beneath the skin. To pass to a less important point, Mr. Barrett-Hamilton confirms the old story that the hairs in the dying mole may be radiated around the eye, exposing the tiny black spot at the bottom of a conical cavity. As Bartholomæus Anglicus wrote in the fifteenth century: "And some men trow that the skin of the mole breaketh for anguish and sorrow when he beginneth to die, and beginneth then to open the eyes in dying that were closed in living."

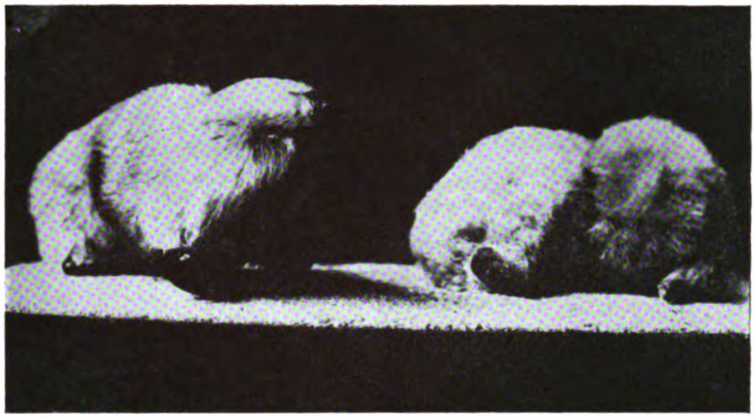


Photo: E. J. Manly.

THE MARSUPIAL MOLE OF AUSTRALIA (*Notoryctes typhlops*).

This interesting mole-like marsupial was discovered by Professor Stirling in Central South Australia. It is a burrower, with pale golden red fur, without external ear-pinna, with very strong third and fourth front claws, and a small pouch opening backwards. It feeds on ants and the like. It is not related to moles, though it shows similar fitnesses.

What other burrowers are blind? In the South African Golden Mole, famous for its beautiful iridescent hair, the eyes are degenerate and covered with skin. In the Spalax of Egypt, which makes burrows thirty feet long, the eyes are "mere black specks among the muscles, but they appear to have a proper organisation." In the so-called Marsupial Mole of Australia the eye is hidden and very rudimentary. Thus we find the same phenomenon cropping up in three quite distinct orders of Mammals—namely, Marsupials, Rodents and Insectivores. We cannot help wondering again whether some constitutional weakness of eyesight was one of the original factors prompting the ancestors of these burrowers to seek the darkness of the underworld. It must be remembered, however, that an exposed eye is apt to be a weak spot in a burrower, and that variants in the direction of reduction and concealment of the eyes would probably get on better than

Photo: E. J. Manly.

THE AFRICAN GOLDEN MOLE (Chrysochloris).

A distant relative of the European mole, represented by several species in South Africa. The name "golden" refers to the iridescent hairs mingled with the softer non-iridescent fur. It is a burrower and the eyes are covered with skin. The structural arrangements for digging are quite different from those of European moles, but the superficial resemblance is strong.

those in which these structures remained prominent and became scratched and sore.

In some of the burrowing snakes the eyes are small, and hidden; in the limbless Amphisbænid lizards, which are sometimes called "snakes with two heads," so difficult is it to tell one end from the other, the same is true; in the Cæcilians, which are limbless amphibians with earthworm-like habits, the retrogression has gone further. As to our British slow-worm, a limbless lizard, it is a pity that it should be called a blind-worm, as it often is, for it has perfectly well-developed eyes with movable lids.

We shall not follow the more or less blind burrowers among backboneless animals, but it is interesting to notice the case of the white ants termites that do not avoid the light, and it is interesting to notice that the workers in these forms have well-developed eyes like the kings and queens. There can be no doubt that having eyes is the original condition among termites, for some of the blind workers that labour in darkness have very minute vanishing points of eyes. Along with blind burrowers we might include blind parasites, but we must pass on to another group.

The third great group of blind animals includes those that live in the darkness of the oceanic abysses. Many deep-sea animals, such as crustaceans and fishes, are blind, and have found compensation in a high development of tactility. But a puzzle arises here: that while some deep-

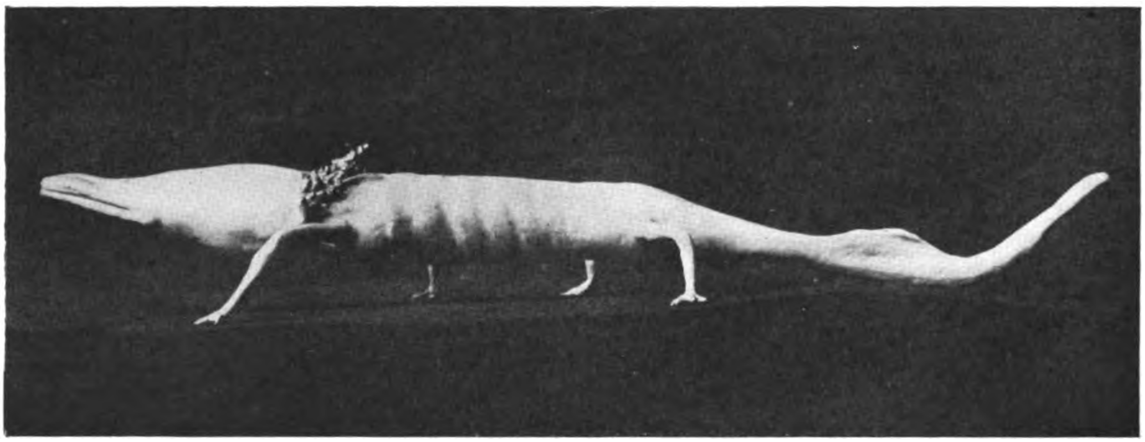


Photo: E. J. Manly.

THE AMERICAN BLIND NEWT (*Typhlomolge rathbuni*).

This blind newt from Texas is interesting in itself and also in being a near relative of the European Proteus. The eyes are completely hidden as in Proteus, and the skin has the same white colour. All the specimens hitherto obtained have come up with the water from an Artesian well 188 feet deep. They probably feed on crustaceans that live in the dark waters.

or termites. Many of them are what may be called darkness-loving animals—they hide underground or in the recesses of the termitary. If they make a foraging excursion up a tree they build a tunnel of salivated earth so that they are not exposed to the light of day. The workers are all blind, a fact which adds to the marvel of their architectural achievements. The males and females have eyes, and this may be connected with the fact that they are winged and spend a short time in the open. But when the queen settles down to maternal functions, sometimes laying sixty eggs in a minute, she becomes partially blind. There is a very striking individual degeneration of the eye. The male escapes this by dying young. But there are some sea fishes have eyes in a state of extreme degeneracy, they form but a small percentage of the total. Moreover, many of the abyssal fishes with well-developed eyes have them of unusually large size and very highly differentiated, as in the case of the upstanding "telescope eyes." It is possible that the large eyes and those with a very big lens, a very convex window-pane in front, and a retina divided into two portions, are specially adapted for utilising the fitful gleams of phosphorescent light that emphasise the darkness of the deep sea. One does not need to go to the true deep sea to find a good example of a darkness-loving marine animal with degenerate eyes. In the strange, old-fashioned Myxine (the glutinous

Photo: E. Step, F.L.S.

THE LONG-EARED BAT (*Plecotus auritus*).

The Long-eared Bat is found from the South of England to the Caledonian Canal. It can be known from all the other bats by the large size of the ear trumpets. There is a long tail and a well-developed skin-bag between the thighs (the inter-femoral membrane).

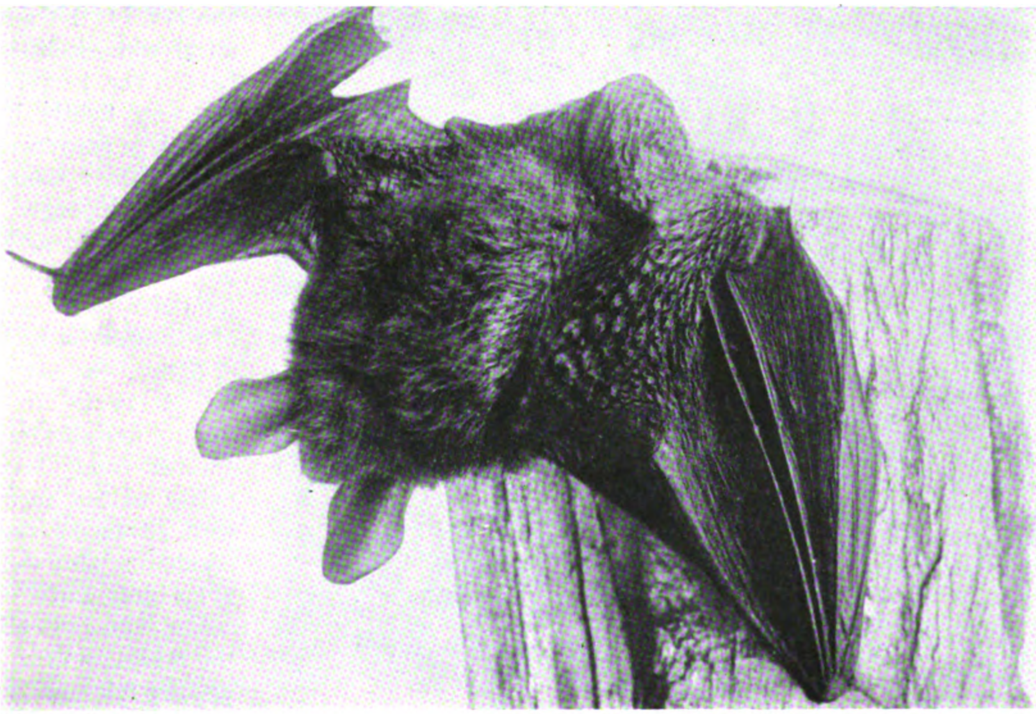


Photo: Harold Bastin.

THE LONG-EARED BAT PREPARING FOR FLIGHT.

This bat is seldom seen till after sunset, and it retreats before dawn into holes under tiled roofs or some such hiding-place. It is a tamable creature and Sowerby tells of one that would take an insect very gently from its patron's fingers or mouth.

hag), a primitive Vertebrate not up to the level of fishes, the eye is arrested in the course of its development. Every Vertebrate eye is, to begin with, an outgrowth from the brain, but the hag's eye stops on the way out. It is little more than a cup filled with connective tissue. But this brings us back to the old puzzle: Is the hag blind because it has been for ages a dweller in darkness, or did the hag seek out the deep dark water because it had very poor eyes?

Bats.

The spirit of Nature must surely have smiled when bats evolved from climbing and swooping insectivores, for it is practically certain that this was their origin. Are they not incomparably quaint creatures, hanging themselves up by their toes, wrapping themselves in their arms? They have solved the problem of flight, but their solution is quite different from that of birds, coming nearer what we see in the extinct dragons or pterodactyls. They are mammals through and through, covered with hair and giving milk to their young, and yet they are as aerial as most birds. Like whales that breathe dry air in spite of their pelagic habit and prolonged immersions, like duckmoles which break down the definition of mammals by laying eggs, bats illustrate nature's capacity for making a contradiction in terms a great success.

It is interesting to think over the adaptations of bats to aerial locomotion—a successful venture which has reacted (in a way difficult to think out clearly) on old-established structural arrangements. There has been an extraordinary *correlation of variations*. The extension of silky skin that forms the pliant, elastic wing-membrane begins at the side of the neck, passes along the anterior surface of the arm, skips the clawed thumb, and is stretched out on four very long fingers, of which only the first has ever a claw, and that only in a small minority. From the posterior surface of the arm the membrane reaches along the sides of the body and is continued down the leg as far as the ankle. An accessory membrane, usually in part supported by a gristly or bony yard-arm, arising from the ankle, extends between the hind-legs, including the tail if there is one. The wing-membrane has drawn the leg strangely outwards; and the knee points, not forwards, as in all other mammals, but backwards. This is another of the anatomical whimsicalities of bats. The long bones are very lightly built, with large marrow cavities; the shoulder-girdle is strongly developed; the breastbone has a prominent keel for the better insertion of the powerful muscles of flight; the vertebræ of the back are but slightly movable on one another and become partly welded together with advancing age—a peculiarity also seen in flying birds, and of obvious advantage in giving the wings a firm, unyielding fulcrum against which they can deliver their stroke.

Photo: Frances Pitt.

A GATHERING OF LONG-EARED BATS (*Plecotus auritus*).
One of the commonest of British bats, with ears of a length almost equal to that of the entire head and body. The fur is long, soft, and silky, brownish in colour, lighter below. The expanse of wing is about ten inches. When it is resting, this bat tucks its ears under its arms, and it can fold one in, while the other stands erect. It is arboreal in habit, and often picks its insect-booty from the leaves and twigs.

Compared with the

Photo: Frances Pitt.

THE PIPISTRELLE ABOUT TO TAKE FLIGHT (*Pipistrellus pipistrellus*).

The smallest, commonest, and most widely distributed British bat. The expanse of wing is less than nine inches. It has brown fur, subject to considerable colour-variation. It usually flies low and is fond of gnats and daddy-long-legs. When it catches its prey, it often presses it against the skin-bag between the hind-legs—the inter-femoral membrane. The natural voice is hardly perceptible to human ears.

fore-limbs, the legs are extremely weak, and it goes without saying that a bat cannot stand up. Although it usually alights on its resting-place head upwards, and may remain fixed by its thumbs, the commoner position when at rest is head downwards, clinging by the well-clawed toes of both feet or of one. When it shuffles along a branch it pushes itself forwards with its feet, which are turned forwards and inwards, and hauls itself onwards on its wrists with the help of the clawed thumbs. It uses first one foot, then the corresponding thumb, then those of the opposite side. We are reminded of the description in the Mosaic law—" the fowl that creeps, going on all fours." When we watch a bat quietly resting on all fours, we notice that the knees are turned upwards and that the elbows are touching them —a quaint posture. It should be noticed that there are some bats which do not hang themselves up to sleep, but lie stretched out.

Bats can launch themselves into the air even from off the ground, and their flight is masterly. In a room they are wonderfully clever, avoiding obstacles such as readily capsizable ornaments, diving under a sofa, and looping the loop; in the open air they vie with the birds—the doublings are so rapid, the disappearances so baffling, the somersaults so sudden, the captures of moths and gnats and flying beetles so unerring, and all so noiseless in spite of what the poets have said about " whirring wings." Some bats can even drink from the river while on the wing, but there are of course great individual differences—thus, a serotine is leisurely compared with a noctule, and a pipistrelle is vacillating compared with a horse-shoe bat. When " scouting bats begin their giddy round," they utter thin, high-pitched cries, which are sometimes, as in the long-eared bat, such " needle-points of sound " (as Phil

Robinson neatly puts it) that many observers with quite normal hearing fail to catch the note. In other cases, however, as in the noctule, the querulous sharp cry is easily heard ; and the fox-bats of the East chatter volubly like monkeys.

The accessory (interfemoral) membrane between the legs is best developed in the long-tailed insectivorous bats, and helps them to double quickly in the air when hunting moths, and also serves as a sort of bag to which booty may be consigned. In a few cases there is an actual pouch on the membrane. In many cases when a bat has caught an insect in mid-air, it bends its head downwards and backwards, and presses its booty against the interfemoral membrane, giving a bite or two or swallowing without risk of loss. In so doing it sinks a little in its flight. In the fruit-eating bats the tail is small or absent. Most bats are small, delicate creatures, but they have a relatively big chest capacity, a strongly developed heart, and large lungs—a triple fitness for flight. It goes without saying that they are on an evolutionary tack quite divergent from that which birds have followed, but it is interesting to notice the numerous "convergences," similar adaptations to similar problems—e.g., the hollow girder type of long bone, the fusion of dorsal vertebræ, and the keel on the breast-bone.

According to old experiments, bats with bandaged eyes can fly about in a room without touching threads strung across it, can traverse a crooked passage without knocking against the sides, and can detect from some distance the approach of a man's hand. This extraordinary telepathic tactility has its seat in numerous touch-spots at strategic places, and in numerous sensitive hairs, each with a nerve-fibre entering it, which are distributed on the rather bare skin of the wings, on the sides of the muzzle, and on the delicate ear-trumpets, which often have accessory flaps. If we make sounds near a captive bat we can see the tremulous movements of the ear-pinnæ—such a contrast to our own—which are oriented independently of each other. In no creatures save bats would we find what we see in the common Long-eared bat—ear-trumpets almost the size of the rest of the body. What, as Bell said, would we think of that in a donkey ? It is difficult to know what to say about the nose-leaves which often adorn or at least distinguish the region of the nostrils, except that they are very original. They may be like horse-shoes, masks, bulldogs' faces, fleurs-de-lis. As Mr. Phil Robinson wrote : "Is not a word of gratitude due to a creature that has ventured upon such originality in the matter of nose ? . . . it is always fantastic and unexpected. It is the very orchis of noses." It is an instance of extravagant development, but the significance of the nose-leaves seems uncertain. They may be connected with the extreme "touchiness," but the minute study of them has not revealed, as far as we know, any very special innervation.

The large fruit-eating bats, with the tail rudimentary or absent, with the crowns of the cheek-teeth smooth or with a longitudinal groove, are confined to the warm parts of the Eastern Hemisphere. The

Photo : Frances Pitt.

THE WHISKERED BAT (*Myotis mystacinus*).

This common little bat, here shown on a hand to indicate its size, is in some ways like a pipistrelle but has a hairy face and a notched ear-pinna. It hunts mostly among the trees, and has a very devious flight. Sometimes it flies in the daylight or very early in the evening. During the summer it seems to live a solitary life.

Photo : C. Reid, Wishaw, N.B.

THE NOCTULE (*Nyctalus noctula*).

This large and beautiful English bat has soft yellowish silky fur and an expanse of wing of about fifteen inches. The length of the head and body is over three inches; and the tail counts for about two inches more. Noctules live mostly in hollow trees, and form large colonies. They feed chiefly on beetles, such as cockchafers, and one has been known to eat thirty beetles in half an hour.

largest, *Pteropus edulis* of Java, has a spread of wing of five feet, about half that of an albatross. The great majority of the smaller bats are strict insectivores, but in the family of "vampires" there is a remarkable diversity of diet—some mix fruit and insects, others suck the blood of frogs and mammals, others living by the shore condescend to crabs and fishes. All the insect-eating bats have the crowns of the cheek-teeth covered with sharp cusps like mountain-tops, as in shrews and other insectivores, an obvious adaptation to the better crunching of insects. Bats' hunting is mostly in the air, but there is often a sort of hovering among the branches from which moths and other insects are picked off. In some cases the bat hunts afoot, shuffling along the branches, and then it has been noticed that the interfemoral membrane, with the tail up the middle of it, is directed downwards and forwards and forms a bag into which the booty caught by the mouth is hastily thrust for subsequent consideration. So another of the bat's quaintnesses is making a pocket of its tail!

The small bats of northern countries solve the problem of winter, when insects are conspicuous by their absence, by passing into a state of true hibernation—which is confined to a few mammals. Their "warmbloodedness" breaks down, and they sink into coma, with breathing movements scarcely perceptible, and with the heart beating only some twenty-eight times in the minute. Even in summer, though their temperature is constant, which is what is meant by "warm-blooded," it is much lower than that of typical birds; in winter it sinks until it approximates to that of the confined space in which the bats hang, often in crowded clusters, it may be over a hundred together. There is something almost eerie in the sight of these inert winter-sleepers, who a few months before were racing with the swifts in the summer twilight. The northern bats solve the problem of winter by falling asleep in a hollow tree or in a corner of

the church tower, or under the thatch of barns, or in a crevice in a cave ; the swifts and swallows and most of our British birds give a very different, but equally effective, solution by migrating to " coasts that keep the sun." But while no bird hibernates, there are bats that migrate. Thus the hoary bat of Newfoundland migrates all the way to the Bermudas, across at least six hundred miles of sea ; and one specimen, probably ship-borne, has been caught in Scotland. In connection with the winter-sleep, which all British bats illustrate, it should be noted that the depth of it varies with the species and with the locality. Of some very mild corners it is said that bats may be seen there every month of the year.

Apart from a few North American species, which have three or four young ones at a time, ordinary bats are uniparous, and two is the limit. This is what we should expect, for an aerial mammal would be badly handicapped if the maternal burden were heavy. We refer not only to the ante-natal period (in North Europe from the end of March or beginning of April until June), but to the nursing time (from June until August), when the young bat clings with his toes and thumbs to its mother's hair and with its mouth to its mother's breast, the aerial flitting and wheeling, glancing and doubling, going on as usual. When the mother rests she folds her wings round her child. The females live together in colonies apart from the males until late autumn, when the feminine society is dissolved for a brief space, the time of pairing. But the extraordinary fact is that although pairing occurs in the vigour of autumn, the internal fertilisation of the egg-cells does not take place till the following spring. Thus the disadvantage of having the young ones developing during a starvation period is evaded, and the carrying of the young before birth is reduced to a minimum. Nature's ways are wondrous wise.

Gilbert White had a tame bat which took flies from his hand. "The adroitness it showed in shearing off the wings, which were always rejected, was worthy of observation and pleased me much." Bell describes the playful ways of a Long-eared bat which would fly up and gently remove a little piece of raw meat from between his lips. But there are probably few naturalists who have got on to terms of intimate acquaintanceship with bats. The fact is that most bats are timid, high-strung creatures, and that their brains are of a low order, not very amenable to cajoling. Moreover, many of them have a very disagreeable smell, and their interesting hair, with spirals or whorls of scale-like roughnesses, is apt to be somewhat too abundantly entomological. The Long-eared bat seems to be free from both these reproaches, and has a pleasant way with it; but, on the whole, we must admit that the typical bat is not very approachable. But perhaps this should add to the fascination of " the busy, merry, little harlequin of our English twilight," as Robinson calls the bat in his delightful " Poet's Beasts." It is an epitome of quaintnesses and in its way a decided artistic success. It has suffered much from prejudiced and partial views. For why should we say " blind as a bat," when most of them have eager, acute little eyes ? Why should one of the nimblest and busiest of creatures, that has to work hard for its dainty meals, be reproached as " lazy-lurking " and " torpid " ? Why should a mammal that has solved the problem of flight in a way all its own and has reached a climax of tactile sensitiveness be libelled as an " ominous fowl " and a " dire imp of darkness " ? The poets have a great deal to answer for.

LXIII

ELUSIVE ANIMALS

WE take the familiar cockroaches as types of shy creatures that live in holes and corners—sometimes in shelter under man's shield, sometimes under natural cover. They live what is termed a "cryptozoic" life, effacing themselves rapidly when disturbed.

Cockroaches.

"Black-beetles" some of them are persistently called, but they are not so black as they are painted, and they are certainly not beetles. They are Orthoptera, along with locusts, crickets, stick-insects, and leaf-insects, far removed from Coleoptera.

The common or Oriental Cockroach, *Blatta orientalis*, is really dark brown, and it is worth noticing that Linnæus, who named it, said "ferrugineo - fusca," i.e., rusty-brown. It is an alien to Britain, believed to have been introduced through commerce during the sixteenth century—whence, we do not know, though the discovery of some specimens living under stones and dead leaves in the Crimean peninsula, points to Southern Russia as its original home. It is now found over the whole earth, and the only thing we are quite sure about is that it must have come to countries like Britain from some warmer clime. For it cannot survive in the more northerly countries except as a sheltered member of the house-fauna. The Common Cockroach has a cousin, the German Cockroach, *Blattella germanica*, dark-ochre or tawny, another naturalised alien, which is wild in the more central and northern parts of Europe and Asia. The politically-minded may be interested to learn that this voracious, destructive, comfort-loving creature is called "the Prussian" in Russia and "the Russian" in Prussia—which is in its way a little parable.

Having these two kinds of "black-beetles," we in Britain have more than enough; but there are unfortunately others—the large American Cockroach, *Periplaneta americana*, common in shipping ports, and the Australian Cockroach, *Periplaneta australasiæ*, a very destructive immigrant which probably came from South-East Asia or Tropical Africa. The international compliments implied in the specific names, such as *australasiæ*, are not always justified. The scientific interest is this, that certain cockroaches, living a penurious life in the open in various countries, get linked to a trade-route, and spread over the earth as tenants of warm and sheltered places. We have here a notable instance of the influence of the hand of man upon the animal life of the earth. But there is something rather depressing in the fact that while the total number of different kinds of animals in Britain has not decreased since the re-population after the Ice Ages, we have received rabbit and rat and lost reindeer and beaver, we

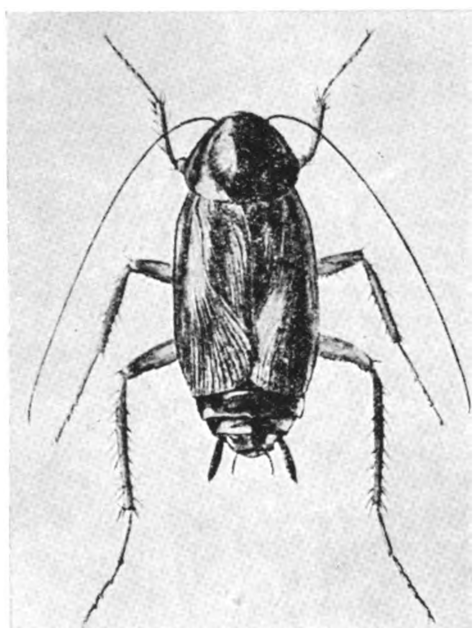


Photo: Reproduced by courtesy of the Trustees of the British Museum (from Natural History Pamphlet No. 12—The Cockroach).

THE COMMON COCKROACH (*Blatta orientalis*).

This cockroach is smaller than the common American Cockroach (*Periplaneta americana*), which has spread over the world in ships. In *Blatta orientalis* the female has rudimentary wings, and those of the male cover about two-thirds of the abdomen; but in the other species both sexes have wings longer than the abdomen. The colour of the former is very dark brown, that of the latter is reddish-brown.

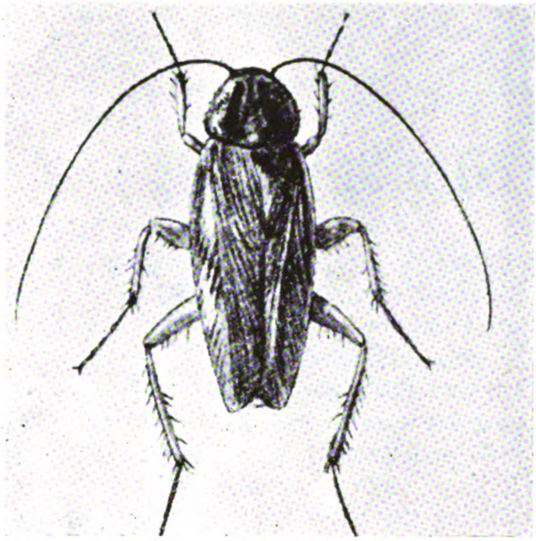


Photo : Reproduced by courtesy of the Trustees of the British Museum (from Natural History Pamphlet No. 12—The Cockroach).

GERMAN COCKROACH (*Blattella germanica*).

This Cockroach is about half the size of the common Blatta. Both the male and the female have fully developed wings. The females are broader and stronger than the males, which they far outnumber. This species is cosmopolitan, and occurs in the open in north-east Europe, though rarely out of doors in Britain.

have received cockroaches and the bed-bug and lost the wolf and the stately Irish " elk." We have lost not in quantity, but in quality of life.

In his treatise on British Orthoptera, Mr. Lucas notes that for any insect to have two colloquial names indicates that it is common and familiar, and as we spoke of " Black-beetles " as a misnomer we wish to say a word about " Cockroach." It is said to be a corruption of the Spanish " cu-caracha," probably meaning some sort of bug (" cuco ") ; and if this is so, we must agree with Mr. Shelford, another authority on these insects, that the American elision of the significant first syllable to give them the name " roach," already appropriated for a fish, is highly reprehensible. So that's that.

What is the secret of the success of the Common and the German Cockroach, not to speak of the others, in countries, like Britain, to which they are certainly not native ? Our three indigenous cockroaches (Ectobius) that live out of doors are much less successful and are practically negligible. The success of the naturalised aliens depends on a variety of qualities. They are nocturnal in their operations ; they run very quickly, they are able because of their much flattened bodies to get into almost inaccessible crevices ; and in becoming domestic they have got away from their natural enemies. Another quality of great survival-value is their wide range of appetite. As Mr. Frederick Laing says in his admirable British Museum pamphlet, " The Cockroach " (1921) : " Nothing which is at all edible comes amiss to them in the way of food. The paper or the whitewash on the wall, books, boots, hair, are all eaten as readily as the daintiest dish." They are very fond of good beer. In a well-known book on the cockroach by Professors Miall and Denny it is observed : " Cucumber, too, they will eat, though it disagrees with them horribly." They have been known to try ink and blacking ; they devour their own cast-off clothes (or moults), their own empty egg-capsules, and their own dead ! As long as they are not full-grown, they have this further advantage, that they can regrow their long tactile feelers and their lanky legs if these get broken—provided always that a little stump is left to serve as a starting-point for the regeneration.

As to family matters, the females of the Common Cockroach are about three times as numerous as the males, and have rudimentary

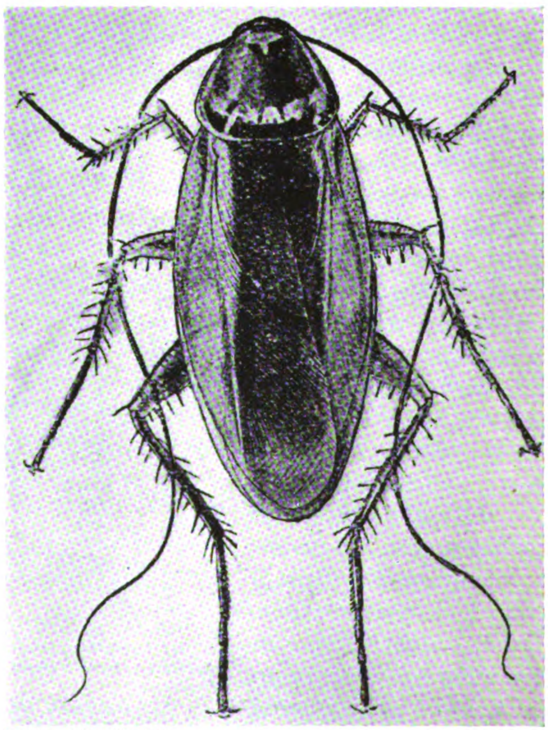


Photo : After Marlett.

AMERICAN COCKROACH (*Periplaneta americana*).

This species attains a length of about an inch and a half. Antennæ, elytra, and wings are all longer than the body. The dark brown egg-capsule contains at most fourteen eggs. As regards food it is practically omnivorous.

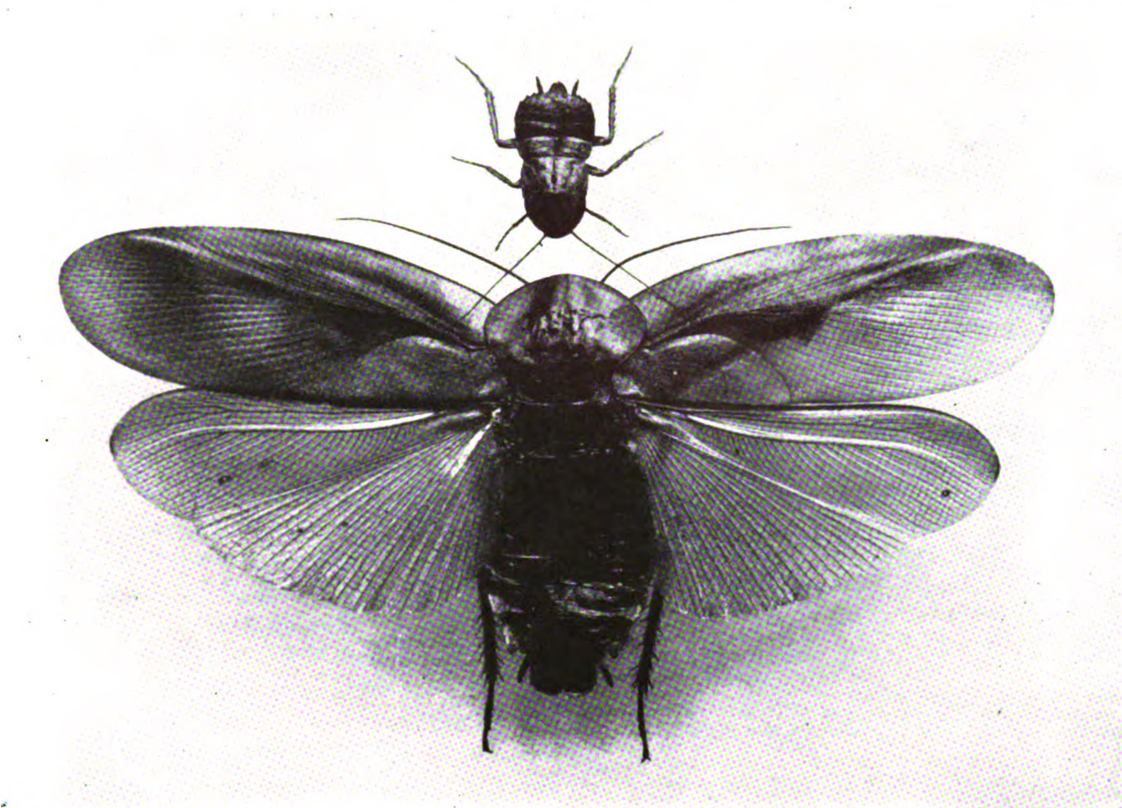


Photo: Harold Bastin.

THE GIANT COCKROACH OF THE TROPICS, AND A FEMALE SPECIMEN OF THE COMMON COCKROACH.

There are twelve families of cockroaches, and the number of different kinds is legion. They have a strong family resemblance, but some are quite wingless. They vary greatly in colour and in size, and there is a robust Madagascar giant, over three inches in length. The large *Blabera gigas* has been detected once or twice in Britain, having come on board ship from the Tropics.

wings. The pairing occurs in the summer months and about sixteen eggs are laid at a time inside a dark-brown egg-capsule, which splits when the young ones are ready to come out. Mr. Laing notices that in most cases only ten or eleven of the sixteen eggs are hatched. The young cockroaches should not be called larvæ, for they are practically miniatures of their parents, though at first very delicate and with hardly any colour. They grow slowly and take about five years to become mature, moulting usually once a year. Perhaps things move more quickly when the conditions are less artificial than those which allow of scientific observation. Not that we wish them to move any faster, for Mr. Laing notes that three females kept in captivity from April to September laid twenty-five capsules. "If we reckon that each laid, on an average, eight capsules, and that out of each capsule ten larvæ emerged, the progeny from a single female would total eighty. The numbers of cockroaches in our kitchens, therefore, can easily be explained."

The German Cockroach is only about half the size of the one we call Common; it is dark yellow or light brown in colour; the females have wings as well as the males, and greatly outnumber them. The egg-capsule holds on an average about forty eggs, and it is carried about by the mother for two to four weeks until the young are ready to hatch out. As in the Common species, the capsule breaks and the young ones put their heads out, but there is this difference that the mother is interested and helps them to escape. The newly-hatched cockroaches are white and cylindrical, able to run about from the first; they soon flatten and become dark in colour. Growth is rapid, and after about five months and as many moults (with a return to the white colour at each disrobing) maturity is reached.

Perhaps there is not much of the romantic about "black-beetles," but their repugnant smell and taste, due partly to the salivary juice and partly to wax-glands on the body, forbid

Photo: John J. Ward, F.E.S.

THE COMMON EARWIG (*Forficula auricularia*).

This familiar insect, dark chestnut in colour with paler legs, varies from three-fifths to four-fifths of an inch in length. The transparent wings are hidden under small pale wing-covers. The callipers or forceps are reddish. Earwigs devour other insects, but they may also sip nectar and damage the gardener's flowers in searching for it.

Photo: John J. Ward, F.E.S.

THE COMMON EARWIG, WITH WINGS EXPANDED.

The wing is like a transparent fan with about a score of ribs. The creature can fly, but it seems very unwilling to display its powers. The mother takes some care of the eggs, and the young ones may take shelter under her after they are hatched. The callipers may be used in adjusting the wings.

impartiality. We say "taste" because it is notorious that they contaminate food carelessly left exposed. But no unprejudiced eye can call them ugly, and a green species we once got in a bunch of bananas was a truly beautiful insect. There is interest also in the glimpse of maternal care that we get in the German Cockroach, pointing on to another kind, that Mr. Shelford tells us of, which carries about its lately-hatched young ones.

The voracity of cockroaches, their contamination of food, and their repulsive smell, mean big black marks against them, and Mr. Laing notes in his excellent sixpennyworth that "their presence in greater or lesser numbers may produce such a mental effect upon the inhabitants of a house as to react detrimentally upon the general health and well-being." He tells us how they may be kept in check by means of traps and an excellent mixture of sodium fluoride and pyrethrum powder. But there is a broader way of looking at the matter, namely, that cockroaches are disposing of "crumbs" (in the wide sense) which are quite gratuitous, and that they are often sheltering in crevices which need not be there. They are comparable in a way to invertebrate rats. Though they have not been convicted as yet of being the vehicles of any disease that affects man, Mr. Laing tells us that the Common Cockroach serves as secondary host to a bacillus which produces cancer in rats.

Although there is very little to be put on the plus side of our account with cockroaches, unless it be that they prey upon bed-bugs, we have reason for congratulating ourselves in one respect that the Golden Age of cockroaches is over and gone. For they are insects of long pedigree, and they were at their climax at the time of the Coal Measures. In his fine Ray Society monograph on British Orthoptera (1920), Mr. W. J. Lucas writes: "Since Palæozoic times cockroaches appear to have decreased in *numbers* greatly, if not so much in *size*, and they must now be looked upon as but a dwindling remnant of a dying race. Let the careful housewife find in this fact what consolation she can: at any rate she may rejoice that the Carboniferous period is past and that she is not required to combat the host of cockroaches which luxuriated in the warm, moist climate of that far-distant age."

We are taking earwigs as representatives of

the old-fashioned terrestrial insects. It cannot be said that they are popular animals, but perhaps that is largely due to the prejudice of ignorance. They are neat and alert; they have a long pedigree; and they have some rather pretty ways. They suffer from the ineradicable superstition that they creep into the ears of sleepers, and worming their way to the brain grow to a fatally large size, "as big as a goose's egg." This is a wide-spread piece of nonsense, for the French name for earwig is "perce-oreille," and the German "Ohr-Wurm." The only fact behind the superstition is that earwigs like to snuggle into dark crannies. Most of them avoid the full light of day and are active in the afternoon and evening. One sometimes finds them in considerable numbers by slitting up a hollow stem like that of hemlock, for they enter by a crack and enjoy the dry shelter. This habit is taken advantage of in trapping earwigs, which is effectively done by taking pieces of elder sticks, pushing the pith out, and corking up one end. This is neater than the common device of putting inverted flower-pots, with some hay inside, on to tops of dahlia-stakes and the like. Among their favourite habitats we must include rotting tree-stumps, flat stones lying loosely, and the burrows of earthworms.

Earwigs.

It is usually stated that earwigs do a great deal of harm in flower gardens. They are much blamed for nibbling at the petals of flowers, like chrysanthemums, dahlias, and phloxes, and gardeners dislike them accordingly. They are also accused of devouring buds, as in the case of hops, and for spoiling fruit. No doubt many of them have a sweet tooth, but we share the heretical view that earwigs are not so injurious as is usually alleged. In many cases they are searching the plant for soft-bodied destructive insects like thrips and green-fly. The common earwig (*Forficula auricularia*) eats the tender shoots of grass and clover, and attacks dahlias and roses and other flowers, yet even in this case the full-grown individuals certainly enjoy insects. There is a seashore earwig, differing from most of its relatives in not disliking the water, and it is well known to devour both living and dead animals. It is clever in catching sand insects, and it will clean up a dead crab or fish. We are not saying that earwigs do no

Photo: G. H. Hewison.

PINCERS OF THE MALE EARWIG.

The callipers or pincers of the male are flattened and irregularly toothed on the inner margin at the base; there is one large tooth where the branch begins to curve; then the branches taper and almost make a circle between them.

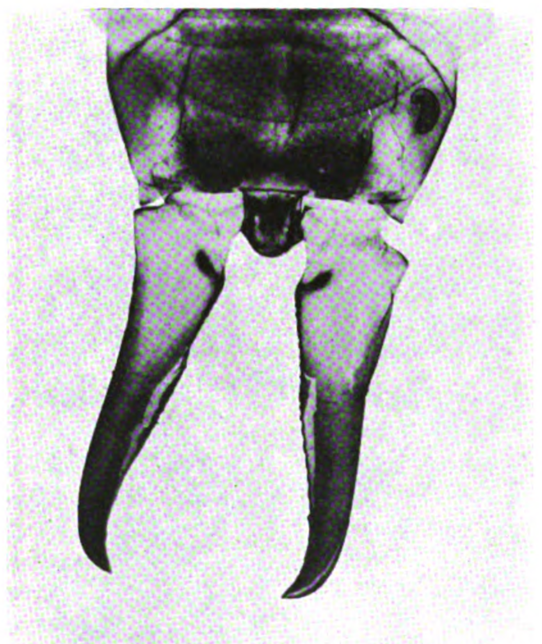


Photo: W. H. S. Cheavin, F.E.S.

PINCERS OF THE FEMALE EARWIG.

The callipers or pincers of the female are simple and almost in contact. They are nearly straight except at the tip. This is a good example of sex-difference or sex-dimorphism. But it must be noticed that there is considerable variability in the callipers, especially in males.

harm, but merely affirming that they are sometimes carnivorous or omnivorous.

Earwigs are old-fashioned insects in the order Dermaptera, not very distantly related to the cockroaches and crickets and other members of the order Orthoptera. The front wings or wing covers are short and leather-like, and neatly folded beneath them there are in many cases relatively large membranous wings, which can be used in flight. There is a beautiful fan-like folding into small compass, so that they can be tucked into small compass beneath the wing

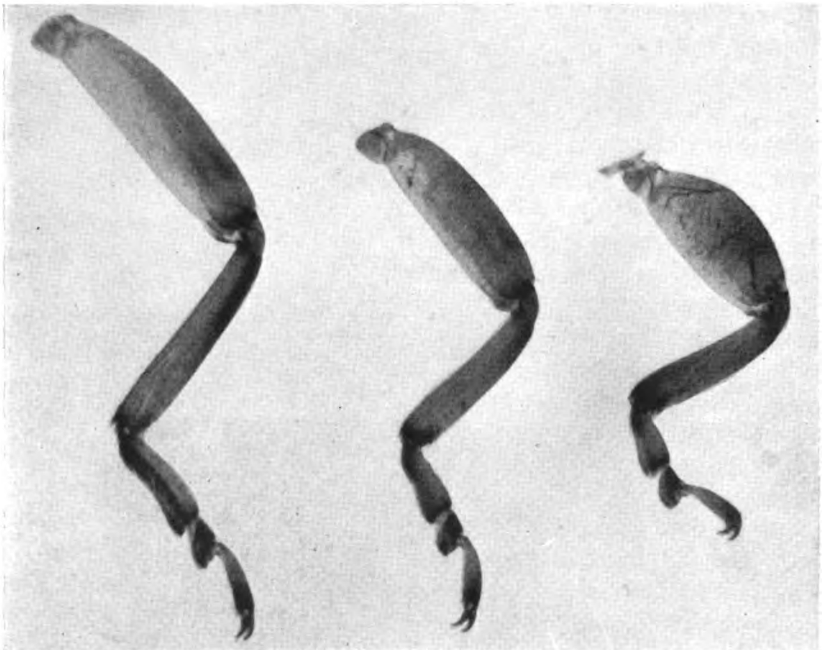


Photo: W. H. S. Cheavin, F.E.S.

LEGS OF THE COMMON EARWIG (*Forficula auricularia*).

Earwigs are quickly moving insects, and their slender agile legs are well adapted. For purposes of identification from books it is important to know the names of the joints of a typical insect's leg. From above downwards they are: coxa, trochanter, femur, tibia, tarsus.

covers. These well developed wings can be readily seen on the common earwig, which is one of the most abundant insects in Britain, yet very few people have seen the creature flying. It is probable that in the majority the neatly folded wings are never unfolded at all. There are many kinds of earwigs which have lost their wings altogether, and have thus returned, like some beetles, to the wholly terrestrial life of the ancestral insects.

A point of some interest is the superficial resemblance or "convergence" between many of the earwigs and certain beetles or Staphylinids, though there is no relationship between them. In both we see an elongated form of body, an exposed abdomen, short legs, much reduced wing covers, active movements, avoidance of light and scavenger habits. But there is one very obvious difference, that earwigs have forceps at the end of their body, and we must say a little about these rather puzzling instruments. The forceps are usually larger, stronger, and more curved in the males, and in many cases there are specific differences between the forceps of the males of related species, while those of the females are indistinguishable. Sometimes there are two forms of forceps in the males of the same species (dimorphism), and there is occasionally a strange inequality in the two blades. They are used in various ways, as weapons, as aids in pairing, and in the folding and unfolding of the wings. The forceps of the maritime earwig can draw blood from man's finger, and they are used in capturing small booty, the body being thrown sideways in a curious wriggling fashion.

Earwigs lay eggs in clusters on or near the surface of the earth, and there may be several broods in the course of the summer. The mother watches over the egg clump, and she continues her care when the young ones hatch out. They are miniatures of the adult, except that they have no wings, and we have seen them run close to the mother when we disturbed them. There is some discrepancy of observation in regard to the degree of the maternal care, and this may be due to differences between the species. It is a matter that should be looked into afresh. There is no ambiguity in what the old entomologist De Geer reported: "At the

Photo: John J. Ward, F.E.S.

1. **THE MOTHER EARWIG WITH HER BATCH OF EGGS.**

A batch may contain about twenty-five eggs, slightly oval, pale yellowish, smooth and shining with a pearly lustre, often laid in a little covered-in excavation in the ground.

Photo: John J. Ward, F.E.S.

2. **THE EGGS COMMENCING TO HATCH OUT A SILVERY-WHITE FAMILY.**

The eggs are laid in winter or in early spring. The young earwigs bite through the egg-membrane and appear head-foremost, about a sixth of an inch in length, very translucent.

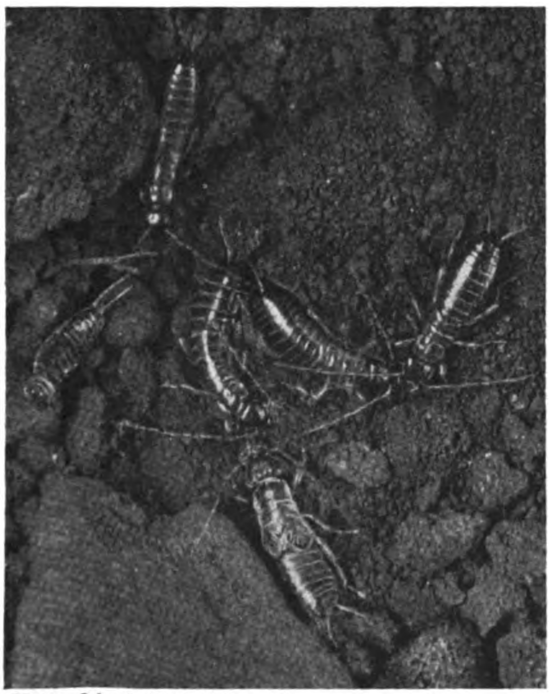


Photo: John J. Ward, F.E.S.

3. **BEFORE THE THIRD MOULT: YOUNG EARWIGS DEVELOPING WING-COVERS.**

The young earwigs are active from the first, and begin feeding in a few hours. The wings are not present in the youngest stages and the cuticle is very delicate.

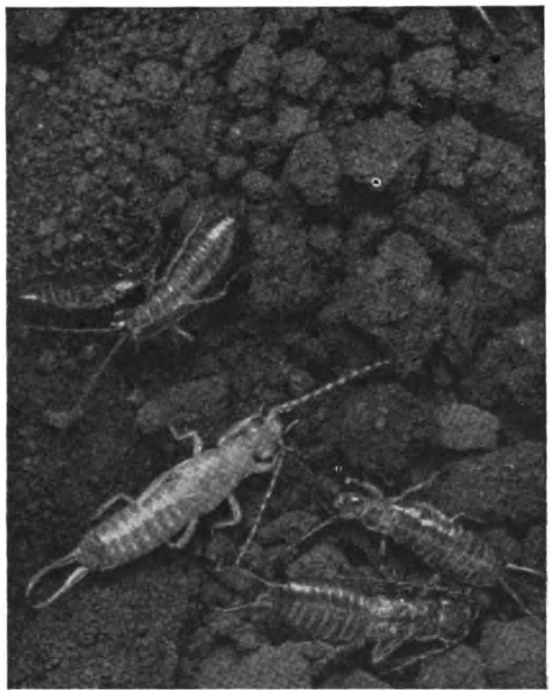


Photo: John J. Ward, F.E.S.

4. **THE EARWIG AFTER THE THIRD MOULT: THE CAST CUTICLE IS ON THE LEFT.**

The outermost "skin," that is the non-living cuticle, is moulted periodically, and this "cast skin" is often eaten by the insect. The story is continued overleaf.

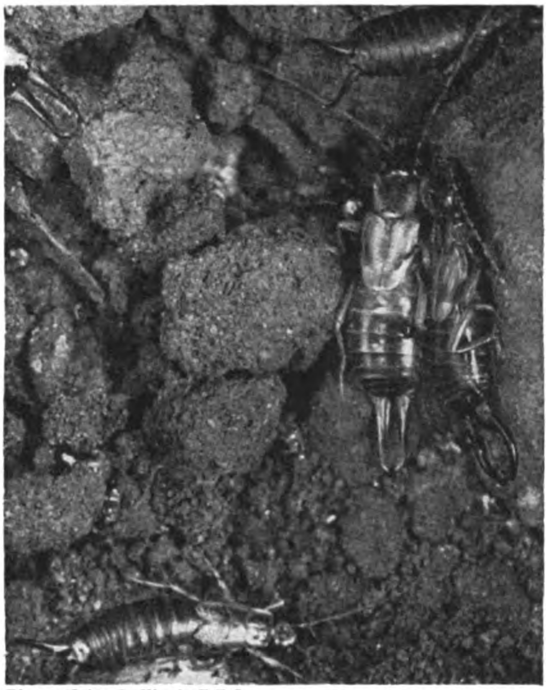


Photo: John J. Ward, F.E.S.

5. TWO EARWIGS WHICH HAVE NEARLY REACHED MATURITY.

Those photographed were hatched on April 23rd, and reached this stage the first week in July. The one on the left has not yet made its final moult.

Photo: John J. Ward, F.E.S.

6. SHOWING THE LAST MOULTING OF THE CUTICLE.

This shows an earwig on a dandelion leaf, pushing off the last husk and withdrawing its snow-white body and tapering feelers. It has black eyes.

Photo: John J. Ward, F.E.S.

7. THE "CAST SKIN" REACHING THE HIND END OF THE EARWIG.

The pincers or callipers at the tail end are used in manipulating the moulting cuticle, finally throwing it clear. In captive earwigs six moults have been observed.

Photo: John J. Ward, F.E.S.

8. THE GHOST-LIKE EARWIG EMERGES, NEARLY HALF AS LARGE AGAIN.

It is here shown on its way to rejoin its relatives. In an hour or so it turns brown in colour. After the full size is attained, moulting stops.

commencement of June, I found under a stone a female earwig accompanied by her young. I placed them in a sand-box where I had put a little fresh earth, and it was curious to see how they ran under and between the legs of the mother, who remained very quiet and allowed them to do it. She seemed to cover them as a hen does her little chicks, and they remained often in this position for hours. Another time I found a pile of eggs on which the mother was seated, and of which she took the greatest care imaginable without ever moving a step away. I took it with its eggs and placed it in a sand-box half-filled with fresh earth, in such a fashion that the eggs were scattered here and there. But soon the mother took the eggs one after the other in her jaws and transported them. After several days I noticed that she had got them all together again in a like place on the surface of the earth, and there she remained constantly seated on them in such a manner that she seemed to cover them." This throws an interesting light on what many people call "those horrid earwigs."

Silver-Fish and such like.

The curious name of silver-fish is given to small wingless insects of various kinds that are not uncommon in human dwellings and stores. When there are so many delightful big animals to discuss, it may seem strange to turn aside to these little creatures, but we wish to have samples of everything in this book, and silver-fish illustrate some points of interest better than do elephants. At the same time we cannot conscientiously say that silver-fish are of any practicable importance to mankind. If they are, we do not know what it is.

Silver-fish are among the minutiæ of the animal kingdom—old-fashioned wingless insects, considered big when they attain to a length of half an inch. We often see them scurrying away in the pantry, and we know of a house where they congregate in large numbers near the kitchen range. They are antiques.

In one of his delightful reminiscent essays, Sir Francis Darwin tells us that he found church service rather tedious in his unregenerate boyhood. One of his time-beguiling devices was to pull threads of india-rubber out of his elastic-sided Sunday boots and make of them little harp-strings, which it was a fearful joy to tweak ever so gently in the sacred precincts. He grew up to be not only a distinguished professor of botany but an authority on strange musical instruments! But we are wandering from the point, which is that a less reprehensible church diversion, he says, was to watch the silver-fish which ran about among the prayer books or among the baize cushions. We confess that we have often shared this diversion, for they are quaint little creatures. We believe that they feed on the vague remains of paste that may be found at the bindings of the old books, which shows that they can make a little go a long way. They are very fond of minute particles of sugar, and these are not unknown in churches. Sir Francis used an apt comparison in speaking of the little silver-fish. He said: "I have not seen one for fifty years, and I may be wrong in believing that they were like minute sardines running on invisible wheels." That is just right. The silveriness is due to microscopic scales with extremely fine lines which cause refraction of light. These scales in the Common Silver-fish (*Lepisma saccharina*) and some of its relatives are used as test-objects for determining the qualities of microscopes. They are striking illustrations of invisible beauty, for their patterns, which are often extraordinarily fine, can only be seen under high magnification. They are also good instances of uniqueness (or specificity), for every different kind of primitive wingless insect has its own particular scale-marking. An expert can sometimes tell a true fish from a single scale; it is possible to do the same with a silver-fish!

When Lord Avebury was Sir John Lubbock he was greatly interested in the very minute creatures we are speaking about, and he made a big Ray Society monograph on them—an arduous piece of classifying work, rather away from his favourite studies of habits and senses, instincts and intelligence. One of his services was to show that there are two distinct orders—the Bristle-tails or Thysanura, which run quickly about in dark dry places, and the Spring-tails or Collembola, fond of moisture, most of which are not only able to run, but have a peculiar instrument by means of which they can jerk themselves up into the air.

There is a little blind Bristle-tail called Campodea, so fragile that you can hardly pick it up intact with a camel's-hair brush, yet

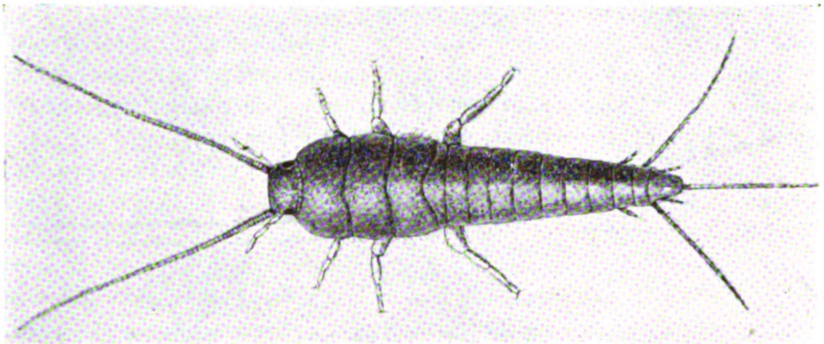


Photo: After Lubbock.

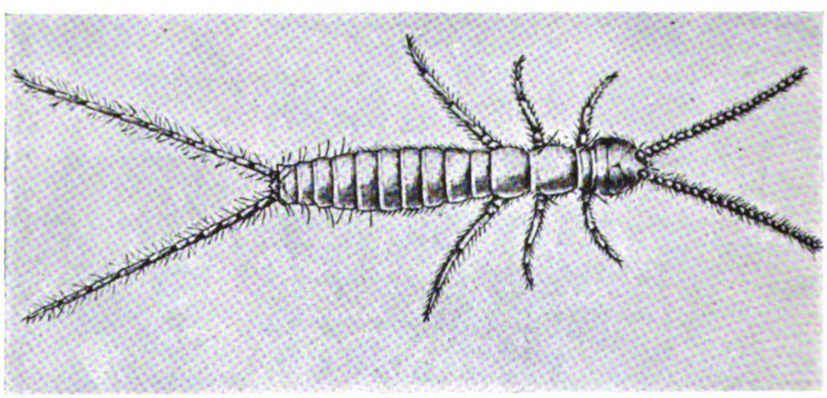
THE COMMON SILVER-FISH (*Lepisma saccharina*).

This is a very common primitive wingless insect, one of the Bristle-tails or Thysanura. It is only known in houses, where it runs quickly about in pantries and the like, seeking for mealy or sugary particles. Its full size is under half an inch; it is covered with very minute glistening scales, hence the name "silver fish."

occurring from the shore of the Mediterranean to the tops of the Pyrenees, and represented in Europe, North America, and India. There is another called Machilis with very beautiful scales which we sometimes see running on the stones of a dry dyke; and it has a relative on the seashore rocks. The silver-fish with which we started is also a Bristle-tail. They are numerous, widespread, adaptable Lilliputians of old pedigree; and when one begins to get interested in them, they have an unaccountable fascination.

The Spring-tails, which Sir John Lubbock called Collembola, are more exciting, for they have, as we said, a remarkable power of jumping. From the posterior end of the body an elastic spring is bent forwards ventrally and clamped in front by a catch. When the catch is pulled forwards, the elasticity of the spring asserts itself; it strikes the substratum; and the creature is jerked into the air. Lord Avebury showed that there are powerful muscles which draw the spring forwards, and others which work the catch. The violent jerk he compared to what occurs when the catch of a drawn cross-bow is released. It must be noted, however, that this account of the Spring-tail's jump is not altogether satisfactory. The catch does not seem very well suited to be a catch, and it is not always present. There is room here for re-investigation. Many of the Spring-tails have another interesting structure connected with locomotion—a minute tube projecting vertically on the under surface about the middle of the body, from which a pair of delicate tubules can be protruded. These have glandular tips and secrete minute drops of gum, which fix the insect to a vertical surface and enable it to rest in that position. Sir John Lubbock turned a Spring-tail upside down on the table and then touched its feet with a glass slide. Out came the glutinous tentacle-like tubules and the insect anchored itself to the glass.

On a well-shaded pool by the side of a wood we sometimes see a multitude of Spring-tails (*Podura aquatica*) covering the surface. In their colour and minuteness they are curiously suggestive of floating iron-filings. Other Podurids, known as snow-fleas or glacier-fleas, are sometimes seen in inconceivably large numbers migrating over the snow or ice. They are probably passing from their winter-quarters in the earth to the water-pools where they spend the summer. It is said that when animals are built on a very minute scale the extremes of cold and



THE BRISTLE TAIL (*Campodea staphylinus*).

This is a typical representative of the primitive wingless insects, the Thysanura, and is common throughout most of Europe in gardens and fields and in damp decaying wood. It is said to occur also in North America and the East Indies; and, in spite of its fragility, it must be a very plastic insect. It is white in colour, delicate in build, blind and light-shunning. There are long feelers in front, and long bristly filaments behind.

Photo: After Lubbock.

SPRING-TAIL (*Smynthurus luteus*).

This is one of the Collembola that have a leaping apparatus. The body shows a comparatively large head, a somewhat globular abdomen, and a small thorax between the two. The spring has two forks and projects forwards ventrally from the hind end. It is kept in place by a catch. In this type there are also two delicate tubes that can be protruded ventrally from the front of the abdomen. Their use is uncertain.

heat are not so much felt as they would be in larger creatures of the same general type. In any case the Spring-tails can stand almost anything except drought and the glare of day. On the surface of small pools of water on the melting ice of the mer de glace at Chamonix, M. Vallot observed in 1912 an extraordinary multitude of a rather rare Spring-tail (*Desoria nivalis*). They occurred over a stretch of glacier twenty metres broad by two thousand metres long, and there must have been forty millions of them.

Another instance of adaptability is afforded by the occurrence of crowds of another Spring-tail, *Anurida maritima*, on the surface of our shore-pools. When the tide comes rushing in these Spring-tails shelter in the crevices of the rocks; but they can survive prolonged immersion. It is almost impossible for them to get wet, for when they are out of the water an envelope of air collects among the minute hairs of the body, and this keeps them dry for a considerable time when they are submerged. Spring-tails and Bristle-tails eat the crumbs that fall from Nature's table, and, from their point of view, man is part of Nature. So far as we know, which is not very far, they prefer vegetable crumbs. They have not many "habits," but we must not think of them too much as miniature sardines rushing about on invisible wheels and searching for crumbs too small for other creatures to see. They have their finer moments. Thus Sir John Lubbock says of *Smynthurus luteus*, a common Spring-tail of our meadows, that "the males are very attentive to the females, and caress them lovingly with their antennæ." There is "love" as well as "hunger," here and everywhere!

Why do naturalists get so much interested in these tiny wingless elusive creatures? The first answer is that they are quaintly, though not very obviously, beautiful; that they are *individual*—themselves and no others; and that we do not know a great deal about them. The second answer is that they are primitive, old-fashioned types, without trace of wings, with antique mouth-parts, with limbs on their abdomen which no reputable insect has in adult life, and with hardly a trace of the metamorphosis so common among insects. They are survivors of very ancient days. The third answer

Photo: After Lubbock. MARINE SPRING-TAIL (*Anurida maritima*).

Spring-tails are primitive wingless insects, in the order Collembola, differing in many ways from the Bristle-tails or Thysanura. Thus most of them have a spring-like arrangement below their posterior body which enables them to leap suddenly into the air. The leaping apparatus is not present in the family Lipuridæ, to which the marine Spring-tail belongs. This creature lives among the rocks on the shores of the English Channel, and can endure prolonged immersion.

is that they illustrate survival in spite of handicaps. The fact is that these Lilliputians are highly successful; they are saved by their minuteness, their dislike of the light, their quickness, their crumb-diet; they have found niches of opportunity all their own. This is an aspect of evolution that one is a little apt to forget—the success of the elusive.

In turning over a heap of road-trimmings by the wayside, or in breaking up a mouldering tree-stump, one always disturbs a crowd of curious creatures. Amongst them one finds a few hundred-footers or centipedes, usually going singly and hurrying off with great celerity when molested. But there are also thousand-footers or millipedes, usually in small companies and leisurely in their movements. If one lays a finger on a centipede, it turns round and bites; if one lifts the millipede, it coils up in a flat spiral like a watch-spring.

Hundred-footers and Thousand-footers.

To many people there is something repellent in these creatures, which are certainly consummations of wriggliness. Perhaps it is the suggestion of snakes in miniature that raises a prejudice against them, but no one can call them ungainly or their movements ungraceful. Perhaps there is something displeasing in the very frequent repetition of similar rings and limbs, for we do not like the same thing over and over again; and although the names hundred-footed and thousand-footed—centipedes and millipedes—are popular exaggerations, there is often an almost tiresomely large number of uniform rings and legs, or, more technically, segments and appendages. Perhaps the fact that centipedes have poison claws, which sometimes give a painful wound, is sufficient to account for the repugnance with which many people regard them, and it would be natural enough to extend the reproach to the quite innocent millipedes. Some common British centipedes are about an inch and a half long (e.g., Lithobius), and millipedes (e.g., Julus) a little less; but in warm countries both kinds may attain a length of over eight inches. The big centipedes have an aggressive air and look quite fearsome.

When we watch centipedes and millipedes at their ease our first impression is of effective locomotion. The centipedes hurry along almost

Photo: F. W. Bond.

GIANT CENTIPEDE (*Scolopendra gigas*).

The body has twenty-one to twenty-three rings, each with a pair of legs, the last pair very long. Whereas millipedes are generally cylindrical in section, centipedes are flattened. Whereas millipedes have short feelers, those of centipedes are long, with at least twice as many joints. Centipedes are poisonous and carnivorous, while millipedes are innocent and vegetarian. The fact is that centipedes and millipedes are not very nearly related.

THE LIFE-HISTORY OF A COMMON BRITISH MILLIPEDE

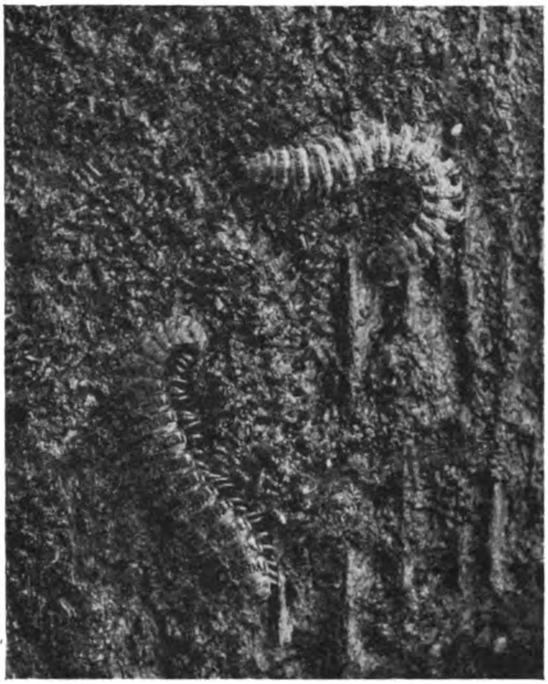


Photo: Hugh Main, B.Sc., F.E.S.

1. THE MALE AND FEMALE (*Polydesmus complanatus*).

This millipede has a cylindrical body with nineteen rings or segments, all but the three foremost bearing two pairs of legs. There are no eyes in the family Polydesmidæ.

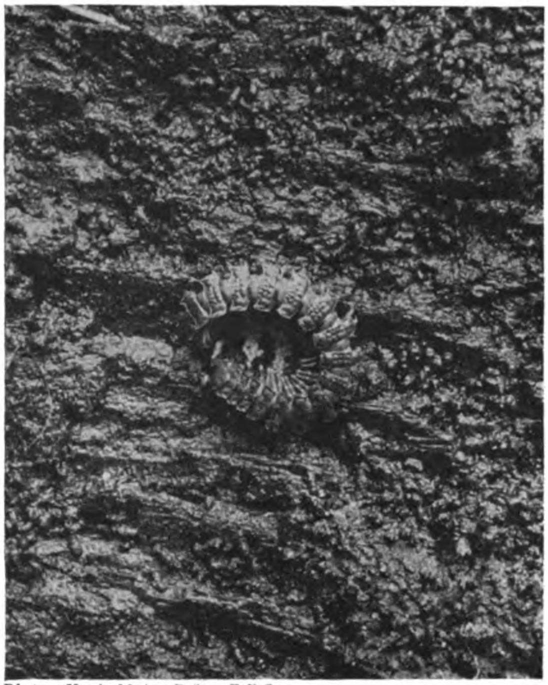


Photo: Hugh Main, B.Sc., F.E.S.

2. THE NEST SOON AFTER STARTING.

The nest is made of earth, which is swallowed by the female, passed out at the posterior end of the food-canal and moulded into shape by the anal flaps.

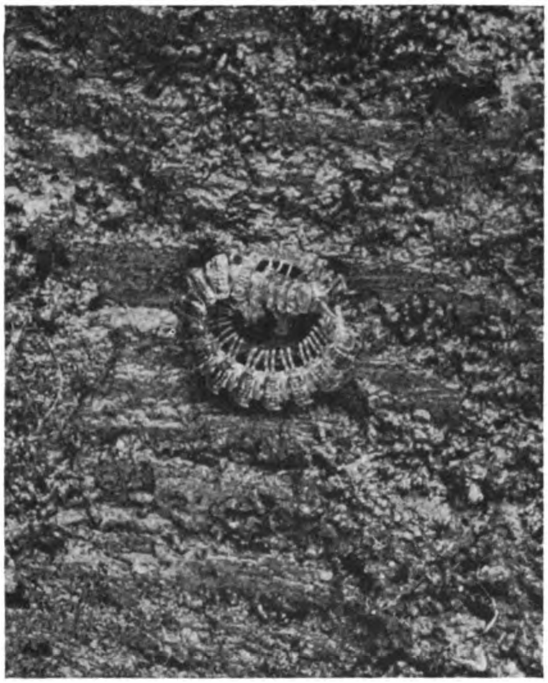


Photo: Hugh Main, B.Sc., F.E.S.

3. THE EGGS BEING DEPOSITED FROM OPENING NEAR HEAD.

The eggs are deposited, two at a time, from the ovipositors situated just beyond the second pair of legs. In centipedes the eggs are liberated at the posterior end of the body.

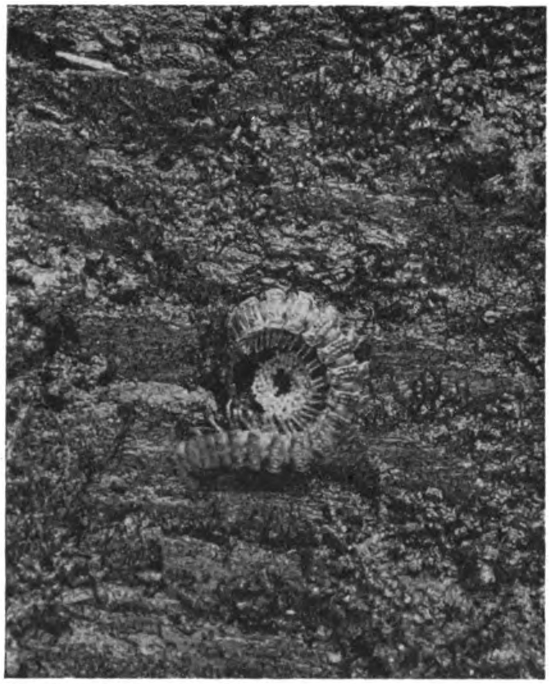


Photo: Hugh Main, B.Sc., F.E.S.

4. THE MOTHER EATING EARTH.

After some eggs have been deposited, a layer of earth is moulded on like mortar to the wall of the nest, and these operations alternate as often as is necessary.

THE LIFE-HISTORY OF A COMMON BRITISH MILLIPEDE

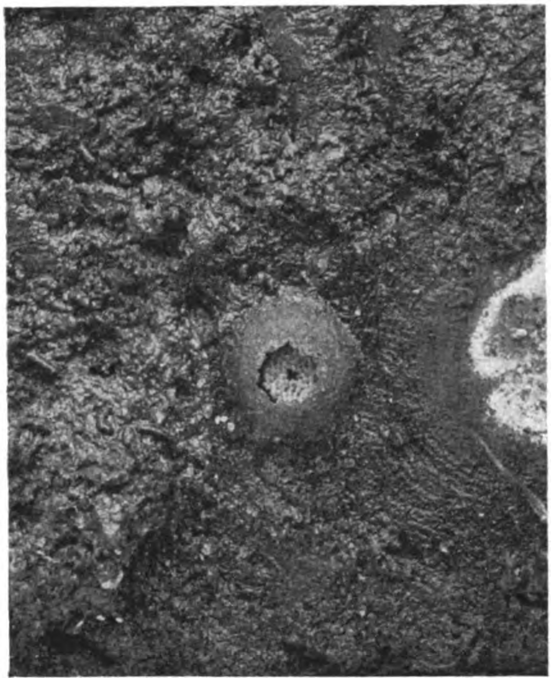


Photo: Hugh Main, B.Sc., F.E.S.

5. NEST AND EGGS: NEST ABOUT HALF FINISHED.

Several pairs of eggs have been deposited; the rising wall of the nest is beginning to assume a dome-like appearance; the female has gone off for a short rest.

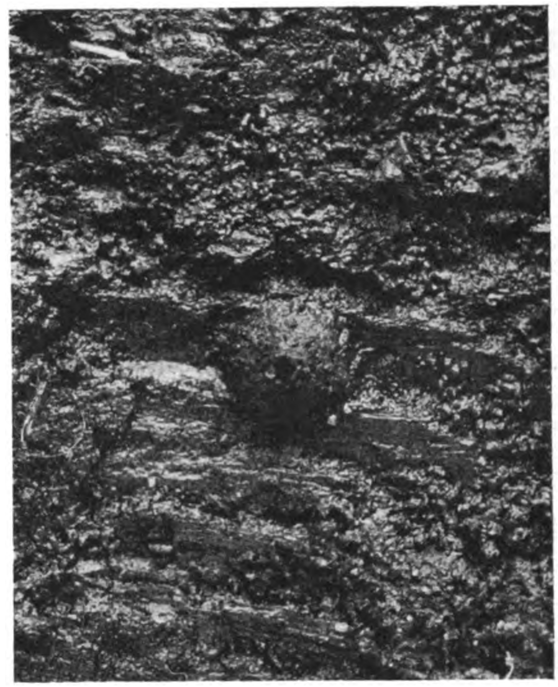


Photo: Hugh Main, B.Sc., F.E.S.

6. DOME COMPLETE AND CHIMNEY ADDED.

The nest has the appearance of a smooth dome—all made of the earth that has passed through the mother-millipede's food-canal. A chimney is now added.

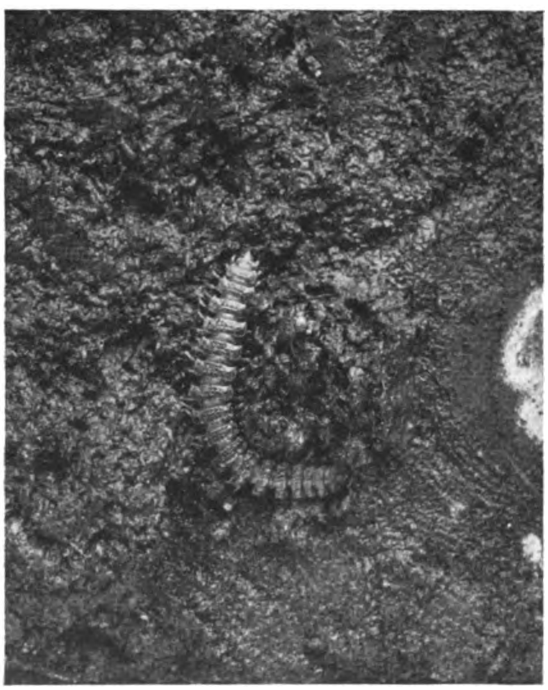


Photo: Hugh Main, B.Sc., F.E.S.

7. NEST COMPLETED: FEMALE RESTING ALONGSIDE.

When the dome is completed and the chimney on the top, the millipede disguises the nest with fragments of earth. Then she rests after her work.

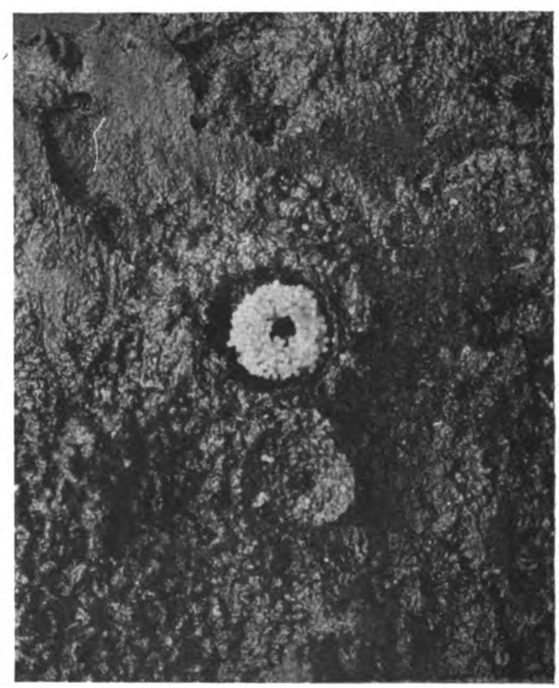


Photo: Hugh Main, B.Sc., F.E.S.

8. NEST OPENED TO SHOW COMPLETE CLUSTER OF EGGS.

The whole process of nest-making, observed and photographed so admirably by Mr. Main, takes about twenty-four hours. As the creatures are very shy, their accomplishments are rarely seen.

fussily and the millipedes are not slow to cover the ground if they are in a mood to do so. Both kinds discover holes where none seemed to exist; they like narrow passages; they wriggle their ringed bodies round rectangular corners; they seem to be able to reverse engines and move tail foremost. What we see is a rowing upon the ground or in the soil, with the multitudinous legs for oars. Each multipede is like a subterranean galley. The legs of ordinary millipedes are too small for observation on the roadside, but one can readily convince oneself that those of a centipede work in relays, and that when those of one group are pushing backwards against the ground, those of the adjacent groups are being moved forward to take grip for another leverage. The movements are so quick that it is difficult to be sure, and it is rather a relief to remember that the most distinguished of living zoologists, Sir Ray Lankester, found it difficult to analyse the order of the centipede's going. He came to the conclusion that if the animal had to work out the problem for itself, it would never get on at all! He quoted the lines, the "Centipede's Problem":

"A centipede was happy quite
Until a toad in fun
Said, "Pray which leg moves after which?"
This raised her doubts to such a pitch,
She fell exhausted in the ditch,
Not knowing how to run."

Photo: Hugh Main, B.Sc., F.E.S.

THE PILL MILLIPEDE (*Glomeris marginata*) AFTER MOULTING.

This compact millipede has eleven body-rings and seventeen pairs of legs. While centipedes have one pair of legs on each ring, millipedes have two pairs, except on the three anterior rings, which have one pair each. The feelers or antennæ are short with seven joints, whereas those of centipedes are long and many-jointed. The Pill Millipede, shown in the chamber, has moulted its cuticle, which is lying alongside.

But the main fact is that the numerous jointed legs, which are full of muscle, are used like oars to row the animal forward. And what a pace the centipede gets up! It reminds one of a miniature railway train.

When we look hard at these wriggling centipedes and millipedes we see that while they are somewhat like one another in being light-avoiding, many-legged, many-ringed burrowers, they are really very different. The centipede's body is flattened from above downwards; the

millipede's is cylindrical. The centipede has a pair of legs on each ring; the millipede has two pairs. Indeed it looks as if the adjacent rings on the millipede's body had coalesced in two's. In the centipede the feelers or antennæ are long and many-jointed; in the millipede they are short and few-jointed. The centipede has the first pair of legs turned into poison-claws; the millipede has no such appendages, and is quite harmless so far as wounds go. The mouth-parts of the two types are very different; and whereas the female centipede lays her eggs posteriorly, the corresponding aperture is situated anteriorly in the millipede.

We have mentioned these details, which might be added to, because they let one into a zoological secret and open up an interesting problem. The fact is that the more we study centipedes and millipedes (often slumped together as Myriopods), the more do differences multiply. The secret is that these two sets of animals are in different classes, not nearly related to one another. The likeness is technically called *convergence*, a term used when a superficial resemblance is exhibited by unrelated animals because they have become similarly adapted to similar conditions of life. Centipedes and millipedes are not closely akin; yet they have an undeniable likeness; this is because both have become suited to progression through holes and crevices. Porpoise and shark are somewhat like one another, being suited in their stream-lines to rapid swimming, but the first is a mammal and the second a fish. Of course, centipede and millipede are not nearly so far apart as mammal and fish; but they are further apart than swifts and swallows, which belong to quite different orders of birds.

We have referred to the different behaviour of the two animals when they are molested. The centipede is more highly-strung; it rushes off; it turns and bites. It is a self-possessed vigorous hunter. The millipede is somewhat lethargic; it "feigns death" or "plays 'possum"; it curls itself up; its only retaliation is to exude from pores along its sides an oily fluid with a repulsive smell. It is a peaceful vegetarian, often inclined to be gregarious.

Our third note is severely practical. The gardener sometimes destroys centipedes and millipedes indiscriminatingly, but this is a mistake. For centipedes are carnivorous and keep a check on many injurious insects, whereas millipedes are vegetarian and often do harm in the garden. In warm countries there are often big millipedes; but they need not be dreaded as big centipedes should be. The fact is that centipedes and millipedes are on quite different lines of life. They are literally on a different footing.

A little more must be said in regard to the way in which the life-circles of these multipedes intersect the life-circle of the supreme biped. The "bite" of a big centipede (from the first pair of legs) means an ejection of poison, which causes pain and swelling. There is some definite influence on the nervous system, for the patient often suffers from dizziness and headache. Centipedes resemble earwigs in their inclination to move into narrow passages which touch many parts of their body. This constitutional peculiarity may account for the fact that they occasionally find their way into man's nostrils. Both centipedes and millipedes may occasionally live for some time in the human food-canal into which they have been obtruded by careless eating.

We have already seen that when the ancestors of our earthworms discovered the underground world, they entered upon a Golden Age of peace and plenty. But this was too good to last, and among the first to follow the earthworms into the underworld were the centipedes—predatory, bloodthirsty, and pertinacious. The ancient feud has persisted through the ages, and it may be watched to-day by the wayside. The centipede attacks the earthworm, clinching its poison-claws. The poison seems sometimes to paralyse the earthworm, for it lies quiet; but in other cases there is a convulsive wriggling, and the Annelid (or Ringed Worm) may throw off the Arthropod (or Jointed-footed Animal), hurling it for some inches along the ground.

But the centipede returns to the attack, and, with or without a further injection of poison, bites the earthworm with his mandibles or jaws, which are cutting-blades without venom. It seems to chew through the body-wall, pressing its mouth-parts close to the victim. In some cases it makes numerous bites near one another, so that a portion of the earthworm's body is separated off. The centipede chews this booty

Specially drawn for this work by Roland Green, F.Z.S.

COMMON COCKROACHES (*Blatta orientalis*).

This dark brown Cockroach, familiarly known as the "black beetle," shows a marked difference between the two sexes. In the male the wing-covers or elytra extend for about two-thirds of the abdomen and the wings underneath are of the same length. The female has a broader abdomen; the wing-covers are reduced to lobes and the wings are rudimentary. The length of the full-grown insect is about an inch, the same in both sexes. In an inset is shown a dark brown egg-capsule, about half an inch long, usually containing two rows of eggs, eight in each row.

at leisure, while the rest of the earthworm crawls away disconsolate. Perhaps there may be a fatal bleeding; perhaps a fly may deposit eggs in the wound, and the last state of the earthworm will be worse than the first. But it may be that healing processes begin, and the earthworm may re-grow a new tail to replace what it has lost.

One can understand how any little improvement might turn the scales. More virulent venom might give an easier victory to the centipede; increased re-growing power might enable the earthworm more readily to survive considerable curtailment. The nimbler the centipede, which does not hesitate to follow the earthworm into its burrow, the more successful it will be as a hunter; but a very sensitive and muscular nullipede (the earthworm) may succeed in parrying the thrust of the multitude (the centipede). Even the worm will turn and toss a centipede or coil round it like a boa constrictor.

Photo: W. S. Berridge, F.Z.S.

A COMMON MILLIPEDE.

The commonest British Millipede is *Julus terrestris*, sometimes called the wire-worm by gardeners. But the true and much more injurious wire-worms are the larvæ of click-beetles or skip-jacks (Elateridæ). No doubt Julus may do much harm in a garden, but nothing to the ravages of wire-worms. The female Julus makes a nut-like nest in the ground, and after she has laid a hundred eggs, she seals it up with salivated earth. The eggs hatch in about twelve days, and miniature millipedes creep out.

Along with cave-animals, we might have taken mites (Acarina) in general,

As Regards Mites.

first, because there are a great many species of mites in caves; and, second, because there are many kinds of mites that live in deep crevices and dark corners that correspond to caves on a small scale. Even the inside of a cheese may be thought of as a cavern. On the other hand, it is well known that many mites are active swimmers, while others move about among the herbage. Others again have given themselves up to parasitism.

Many races of animals have had, or still have, their giants. There are whales and mammoths among mammals; ostriches among running birds; albatross and condor among flying birds; pythons, crocodiles, giant tortoises and turtles among reptiles; extinct amphibians as big as donkeys; great fishes like sharks and congers, and tunnies ten feet long. We need not continue the list, but the general impression we get is that it is not well for an animal to be too big. The gigantic is not a successful line of evolution. Where are the giant terrestrial reptiles, the Labyrinthodont amphibians of the Trias—one of them with a skull a yard long; the Ammonites as big as cartwheels? Each age has had its giants, but the giants do not last.

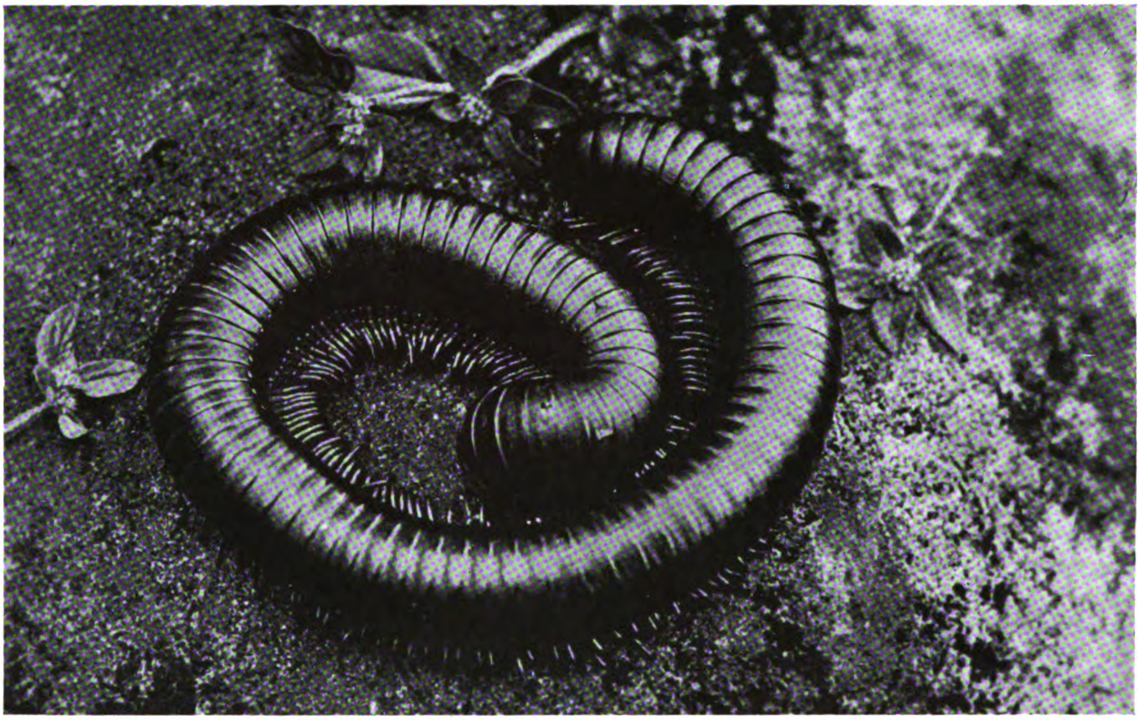


Photo: T. Alexander Barns.

COMMON AFRICAN MILLIPEDE.

This is one of the millipedes that attain a relatively large size, in some cases longer than one's hand. But all are quite inoffensive, except in so far as their " stink glands " secrete a repulsive fluid. The one photographed " feigns death " when touched, and coils into a watch-spring-like spiral.

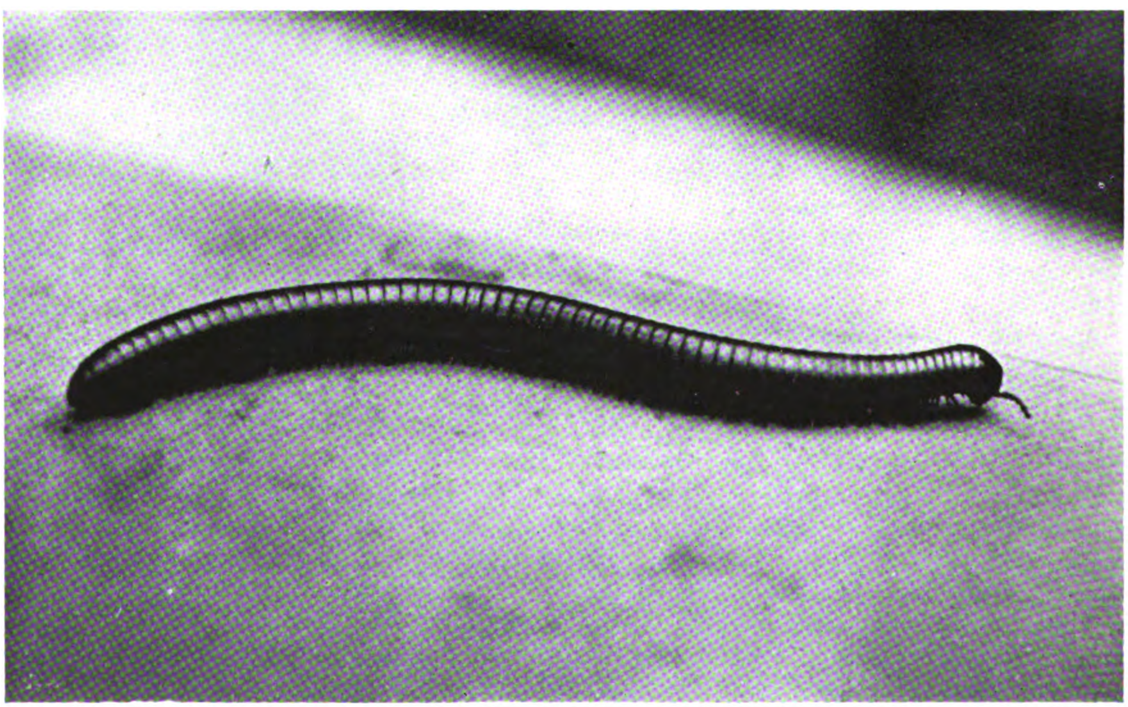


Photo: F. W. Bond.

WEST INDIAN MILLIPEDE.

There is a strong family likeness in most of the millipedes, but there are many of them, and they represent a somewhat archaic type of jointed-footed or Arthropod animal. All are vegetarian and none are poisonous; they live an elusive " cryptozoic " life; rather sluggish; differing from centipedes in almost every respect except general habit and symmetry, and the numerous segments and legs.

Much more successful is another trend of evolution—towards dwarfs; and one reason for success is plain, that minute size makes escape easy. Think of the harvest mouse swinging on the wheatstalk, the humming-bird with a nest the size of a thimble, a tree-frog just over an inch in length, and fishes smaller than minnows. But these are relatively gigantic compared with the minute crustaceans known as water-fleas or with some of the spiders. Smaller still are some of the insects, which may be under a millimetre (one-twenty-fifth of an inch) in size. It is often said that the smallest known insect is one of the Hymenoptera, *Alaptus excisus*, which is about half a millimetre in length. But it has relatives not exceeding one-third of a millimetre, and there are some beetles which are only one-fourth of a millimetre long! This brings us to think of an animal about one-hundredth of an inch in length, and yet containing a full equipment of organs—such as brain, food-canal, and breathing tubes. It rather taxes the imagination!

We feel the same in regard to mites, many of which are quite microscopic, even less than a hundredth of an inch. As it is said in "The Cambridge Natural History," "taken all round, a millimetre may be considered a large size for a mite." Little wonder that their name is legion, that they have a world-wide distribution in crevices or as parasites, and that they are very difficult to eradicate when they once get a foothold. It is probable that the minuteness has its chief value in enabling mites to get at food-materials even when well protected, and to disappear through holes like the eye of a needle, and to feed upon microscopic droplets of juice, sometimes eked out with not less microscopic organic crumbs. But many of them are able to survive for a long time in very unpropitious conditions, and perhaps there are physical reasons why their minuteness helps them to withstand extremes of heat and cold and drought.

Mites or Acarines are not related to insects, but they have affinities with spiders and scorpions. The body is apparently all one piece, except that the foremost part sometimes forms a movable false head—called the capitulum. The posterior part of the body (the abdomen) is unsegmented, except in one case (Opilioacarus). The anterior part of the body consists of head and thorax run together, and in most cases this cephalothorax is marked off from the abdomen by a distinct groove. There are two pairs of mouth-parts suited for sucking, but often also for biting or piercing. There are no feelers, but there are often eyes. There are four pairs of legs, which are often more or less degenerate in the parasitic forms. The more active mites, like harvest-mites, breathe by air-tubes; the more sluggish ones, like cheese-mites, breathe through their skin—the most primitive way of breathing.

What comes out of a mite's egg is almost always a *larva* with three pairs of legs. The acquisition of another pair marks the beginning of the *nymph*-stage, during which there is great activity, followed by quiescence. The outcome is the fully formed adult. The nymph may be very unlike or very like the adult, but there seems to be a considerable internal change marking the growing-up or adolescence. In the "Cheese-mite" family some of the nymphs become strangely transformed, with a hard protective covering on their back, and with adhesive suckers below the hind part of the body. These strange forms—called "hypopial"—fasten themselves by their suckers to insects such as humble-bees, and the meaning of the remarkable change of structure and habit is to secure dispersal. The travelling forms are very hardy and can survive for a long time without food. When their insect-chariot stops at a suitable place the mites let go; and if they are lucky they continue their development, changing back into the ordinary nymph form. This is one of the ways in which mites spread.

There is an interesting variety of habit within the class of mites. The freshwater mites, which are often vividly, sometimes protectively, coloured, illustrate what is meant by *indefatigable*; they are never tired; some of them seem *never* to stop swimming about in pursuit of their prey. Much less attractive is the small group of marine mites that crawl about on seaweeds and zoophytes in the shore area. The "harvest-mites," often velvety red, hunt among the grass for various kinds of small animals, such as insects. When the larval forms of the British "harvest-mite" (*Microtrombidium holosericeum!*) get on to man they fix themselves at the base of a hair and give a bite, the consequences of which are very irritating, especially to thin-skinned people. A little ammonia removes or lessens the pain, and

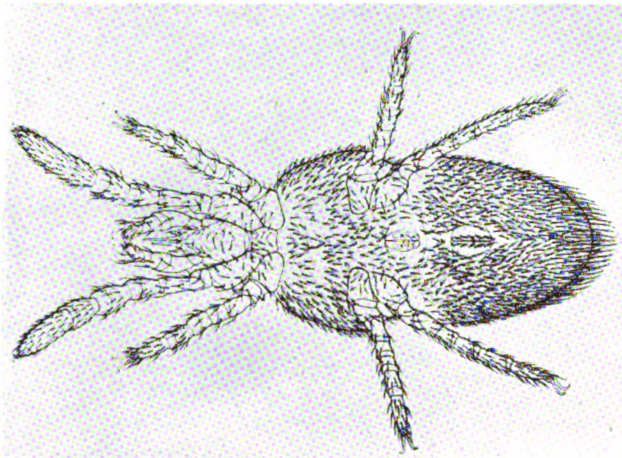


Photo: After S. Hirst.

LARVA OF THE HARVEST-MITE (*Microtrombidium holosericeum*).

The very minute larvæ of this mite fix in man's skin, at the base of hairs, during the hot and dry months of the year; and their bite often causes great irritation. It is useful to apply a little ammonia to the bite, and among the preventives recommended, to be rubbed on about the ankles, for instance, are oil of citronelle and flowers of sulphur.

apart from cases of fortuitous infection, that there has been insufficient attention to cleanliness. On the same lines are those that give poultry their "scaly leg," or cause them to pull out their feathers, and those that give sheep their "scab."

Quite by themselves are the Tarsonemidæ, minute vegetable-eating mites, one of which, now called *Acarapis apis*, was shown by the Aberdeen investigators (Rennie, White, and Harvey) to be the cause of the widespread and disastrous Isle of Wight disease of bees. It is remarkable in having as its haunt certain breathing tubes of the bee, thus illustrating the characteristic mite tendency to explore minute crevices. But the life-history of this serious internal parasite is still imperfectly known. Another famous mite is that which has ruined so many black-currant bushes all over the country. It is a very minute, worm-like mite that feeds between the leaves of the buds, and so irritates them that they swell up and fail to open as they should. The result is well described as "big bud." Not distantly related are the minute, worm-like "follicle mites" (Demodex), which occur in

oil of citronelle applied to such parts as wrist and ankle is a useful preventive. It is not clearly understood why the bite should cause so much irritation, but it is noteworthy that a Japanese species carries a microbe of some sort which induces a serious "river fever," called Kedani disease.

The hard-shelled "beetle-mites," or Oribatids, feed on decaying vegetable matter; the leathery or hard ticks spend part of their life sucking backboned animals, and are instrumental in spreading several serious diseases, such as "tick fever" in man, and "heart-water" in cattle. The "snouted mites," usually red in colour, are free-living and predatory, but their larval forms often hang on to the legs of insects and spiders. Belonging to a different family are the species of Gamasus that we often see clinging to the black dung-beetle if we turn it upside down on the roadside. The so-called "red spiders" (Tetranychus) are sap-sucking mites that do much damage to fruit trees and bushes and greenhouse plants. The popular name refers to their habit of spinning underneath the leaves a silken web, within shelter of which they lay their eggs and continue their sap-sucking. On a very different tack are the "cheese-mites," most of which live upon decaying organic matter, and everyone is familiar with the crowds of miners in the great caverns of the cheese. The itch-mites and mange-mites tunnel in the skin of mammals, clear evidence,

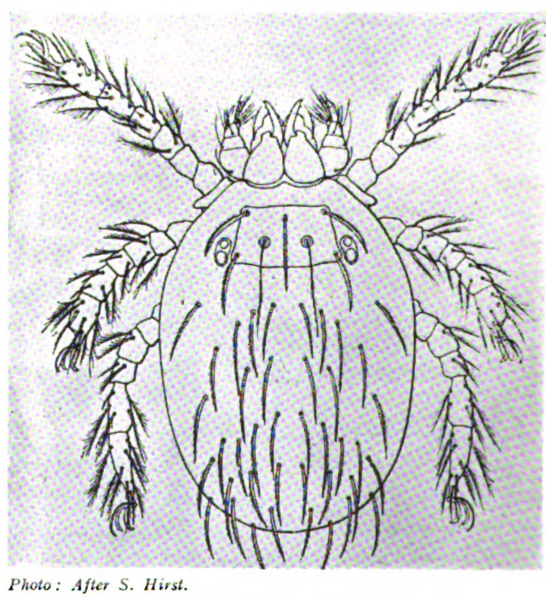


Photo: After S. Hirst.

ADULT HARVEST-MITE (Microtrombidium).

The mite that is popularly called the "harvest-bug" in Britain is probably *Microtrombideum autumnale*, or some would say *M. holosericeum*. As Gilbert White said, it is "very troublesome and teasing all the latter end of summer, getting into people's skins." The colour is bright scarlet-red, and the skin bears numerous minute setæ or bristles.

various mammals in the moats from which hairs spring. The visible anterior ends are familiarly known in man as "blackheads." They must be the commonest of human parasites.

We see then from these samples that the quest for food among mites is very varied. The diverse methods form a sort of epitome of what occurs throughout the animal kingdom as a whole. Carnivorous, vegetarian, saprophytic, parasitic ; borne about by animals, crawling over plants, burrowing in the ground, in freshwater, and in the sea ; what variety there is ! The linkages with other creatures are often subtle ; one mite makes a vehicle of the bee and another invades its interior ; one mite eats the honey in the hive and another mite devours the honey-eater ; and the most subtle linkage of all is that many mites are the carriers of microbes which bring even man to the dust.

Death-watches.

As another example of the burrowing animals that live a hidden life, we take the Death-watch that makes tunnels in old wood, and taps on the wainscot in a way that alarms people who do not know the Natural History of common animals. The Death-watches are little beetles, with a good many characters that make them what is called "ken-speckle" or readily recognisable. The one we know best is not the true Death-watch but a near relative called *Anobium domesticum*, also given to burrowing in old furniture. It is under a sixth of an inch in length, dark brown in colour, somewhat cylindrical in build of body—as if suited for working in tubular burrows. The feelers are long, especially in the last three joints ; the legs can be tucked away under the body ; and the hard wing-covers, hiding the relatively large wings, are marked by longitudinal furrows and by very short-set bristles, like much worn pile. Perhaps the most striking feature is the way in which the head is bent downwards under the shelter of the hard foremost ring of the thorax (let us say "breast-region"), which has the shape of a coal-scuttle bonnet. We suppose that the beetle, when at work within the wood, gnaws with its jaws, and presses forward with its coal-scuttle at the same time. The technical name is, as we have said, *Anobium domesticum*, and it is a second cousin of the true Death-watch (about a third of an inch long), *which used to bear the same designation*. There are many other relatives, such as the smaller Furniture Beetle (about an eighth of an inch long), whose larvæ make the familiar tunnels in "worm-eaten" tables and chairs. It has given its name to a human occupation, for the lady in the police-court deponed that her husband was a "worm-eater"; meaning, of course, that he was employed to make holes in "faked" old furniture. It should be noted that the bulk of the boring is done by the larvæ, and also most of the eating ; besides, of course, all

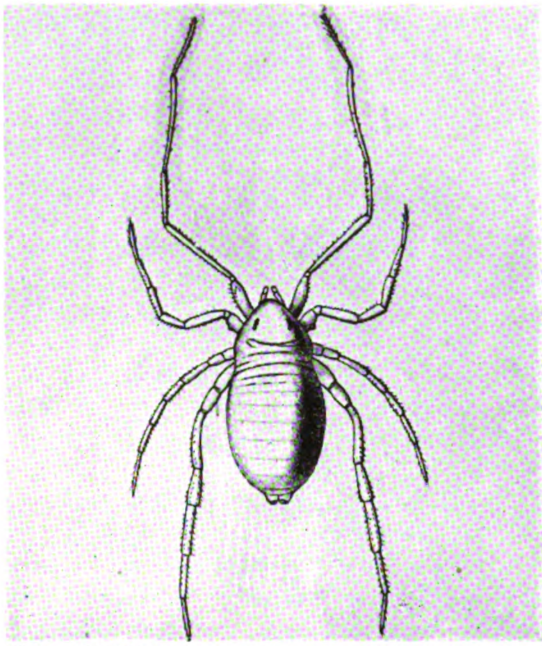


Photo : After With.

A UNIQUE MITE (Opilioacarus).

This mite stands quite by itself, for it is the only Acarine with a segmented abdomen. It has clawed appendages (cheliceræ) just in front of the mouth, somewhat leg-like palps, four pairs of walking-legs, two pairs of eyes, and four breathing pores on the back of the abdomen. Four species are known, from Italy, Algeria, Arabia, and South America.

the growing. For a beetle never grows after it is a beetle.

An interesting feature in Death-watch beetles is the immediate "death-feigning" whenever we shake the tray or piece of wood on which we watch them. Even a slight jar or a jerk with a needle is enough to send them into this strange cataleptic state. At this low level there is no question of deliberate playing 'possum, as a fox might do ; everything points to a racially established tendency to a sort of fit or catalepsy. The inborn tendency works without deliberation whenever there is a threatening jar. When a natural enemy, such as a woodpecker, is on the

search for food, the unconsciously wrought-out policy of the Death-watch beetles is to " lie low and say nuffin."

It may be mentioned that there are other entirely different Death-watches belonging to the family of book-lice (Psochidæ) in the dragon-fly order Neuroptera. Thus there is the tiny wingless *Atropos divinatoria* that runs about among old books and in collections of insects. It is a soft, delicate creature, but it seems to produce an often-repeated tick, which is rather puzzling and should be re-investigated.

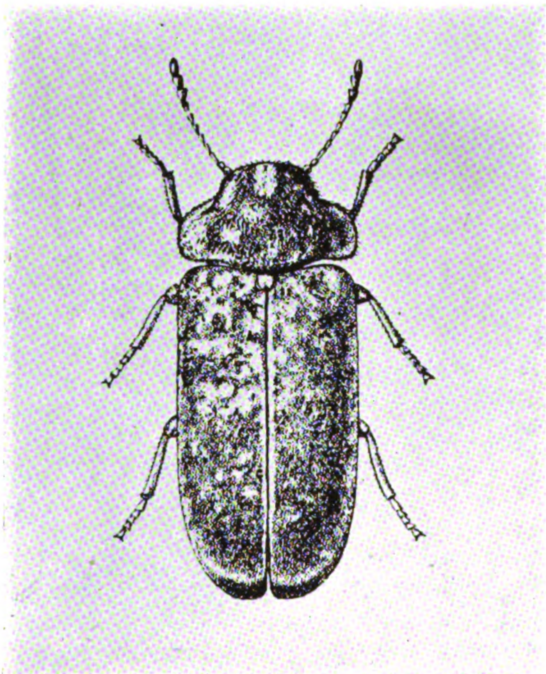


Photo: After De Geer.

THE LARGER DEATH-WATCH BEETLE (*Xestobium tesselatum*).
This beetle, which shares with Anobium the name of Death-watch, is a larger insect, about a third of an inch in length, reddish-brown in its main colouring, sprinkled with patches of pale bristles. When one beetle makes three or four knocks on the wainscot with its head or with its prothorax, there is silence for a moment, and then an answer comes from a neighbour. It knocks by day as well as by night, but it is oftenest heard when all is quiet.

The wood-boring *Anobium domesticum*, with which we started, has a straightforward life-history. Out of the eggs, laid in the tunnels, there emerge minute white grubs, with a soft body, a hard head, and three pairs of legs. They chew the wood with their jaws, and seem to thrive on their dry-as-dust diet, for they grow and moult and feed and grow and moult. No one ever sees them without making excavations, for they lie in the recesses of their burrows. Eventually they sink into the quiescent pupa stage, wrapping themselves up in a silken cocoon with which particles of sawdust are interwoven. The great change occurs, and out comes a small beetle, pale and flabby. It rests a while, becomes hard and brown, and then it goes a-roving. The same kind of story is true of the shorter, broader, and paler *Anobium paniceum*, which is almost omnivorous. It is fond of edible commodities, but it prefers them hard. Ships' biscuits are best of all, but it has been known to eat pictures and herbaria. It is Captain Marryat's " weevil," but it is not a weevil. It is also one of the " book-worms," which are not one, but many.

The Death-watch proper used to be called Anobium, but its name when we looked at the register last was *Xestobium tesselatum*. It is a first cousin of *Anobium domesticum*, but it is a broader, stronger creature, nearly twice as long, and reddish-brown in colour. The tapping is louder than in the previous case, and it is particularly loud at night. Of a truth, however, it speaks not of death but of love, for the tappings are signals between the sexes, and commonest at the breeding season about mid-summer. They can be evoked sometimes by tapping on the wainscot or furniture with a pencil, for then the Death-watch answers back, four or five ticks being the rule. The creature raises itself on its fore-legs and bobs its head up and down, striking the wood with its jaws according to some, but mainly, we think, with the front of the breast-region or thorax. The famous Dutch naturalist, Swammerdam, who worked during the latter half of the seventeenth century—a great time for zoology—suggested the name Sonicephalus, or " Noisy-headed Beetle."

As to the superstition which regards the tapping as a presage of approaching death, it must be remembered that the cause of the insistent sound was unknown until about the time of Swammerdam. In his " Household Insects," to which we are indebted, Mr. Edward A. Butler quotes from one of the earliest descriptions, a paper in the " Philosophical Transactions " for 1698 by Mr. Benjamin Allen. " The second animal I observed is a Death-watch: I have taken some before this, it is that which makes a noise resembling exactly that of a watch: it is faithfully the very same, and lived

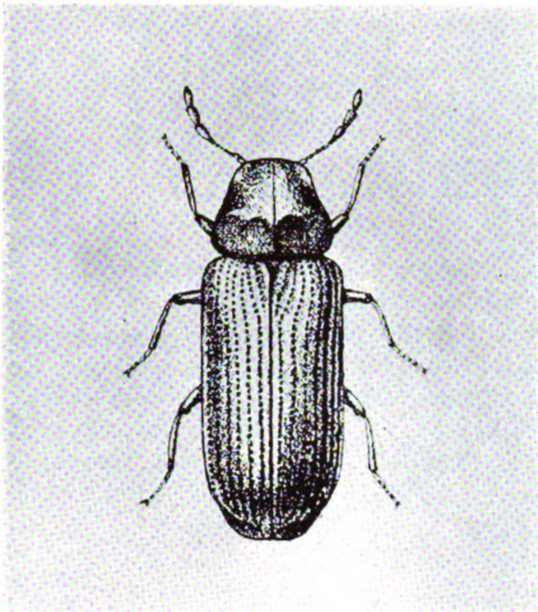


Photo: After De Geer.

DEATH-WATCH BEETLE (*Anobium domesticum*).

This small household beetle is only about a sixth of an inch in length. Its colour is dark brown. The hard wing-covers hide the delicate membranous wings. Most of the boring in wood is due to the whitish fleshy grubs, and they seem to thrive on their dry-as-dust food.

four days with me, beating exactly, for I took two, I suppose one was the female, that is only conjecture." Punctuation was without subtlety in those days! "This small beetle . . . being rarely heard, and not known, has obtained the name of a Death-watch, which yet I have known to be heard by many, when no mortality followed, and particularly by myself, who have taken two of them, seven years since, without my death following that year." We must leave it at that!

In recent years an interesting light has been thrown on the puzzle of the Death-watch's diet. The grubs, like those of the Anobium with which we started, grow slowly for about three years, but they are from first to last plump, well-fed creatures, though their diet is very unpromising. Especially in the case of the larvæ of biscuit-loving *Anobium paniceum*, which have, however, a wide range of appetite, it has been shown that part of the food canal contains an abundance of partner yeasts, which are able to ferment at least some of the hard stuffs that are eaten. So the food of the larval Death-watches is not so dry as it seems. In most cases of insects with partner yeasts the transference from generation to generation is brought about by the early infection of the egg itself; but in the Death-watch the method is quite different. The larva, in biting its way through the chitinous egg-shell, becomes infected with yeast-plants which were entangled on the rough outer surface of the eggs when these were liberated by the mother-beetle.

We must not leave the Death-watches without answering the natural question: How can one get rid of them? Perhaps the best plan is to drench the woodwork with *carefully used* poisons, such as corrosive sublimate, carbolic acid, and formalin; to polish with benzine every day till the beetles are gone; to tie cloths saturated with paraffin round the furniture and expose the articles in the open air for many days; to fumigate the room repeatedly with sulphur. But who is sufficient for these things?

"The eye sees what it brings with it the power of seeing," and the naturalist who has learned to peer or "scrutinise," as Fabre used to say, observes twice as many creatures as the casual onlooker. Yet without probing and sifting, even the naturalist detects only a fraction of the animal population of any area, whether it be a corner of a British wood, a shore-pool, a Tropical jungle, or a quiet reach of the river. Our point in this chapter has been to suggest that one reason for this is the frequency of the elusive or "cryptozoic" habit. For many creatures the only chance in the struggle for existence is to make themselves scarce.

Photo: John J. Ward, F.E.S.

DEATH-WATCH BEETLE (*Anobium domesticum*), SHOWING THE HEAD-HOOD.

The tapping of the male Death-watch is a signal to his mate. The sound seems to be produced by knocking with the front of the thorax, which overlaps the head like a coal-scuttle bonnet. But some observers say the beetle taps with its jaws.

LXIV

RIVERS AND FRESHWATERS

RIVERS and streams are often very beautiful and, as we say, "inviting." But they are not favourite haunts of animal life. Why should the river fauna be so sparse?

The first reason is that the flow of the stream demands strenuous resistance with little relaxation. If they are not to be washed downstream, the animals must have great endurance or else some special adaptation. There must be for most river animals some opportunity for rest—by having grapnels, for instance, or suckers; or by having a home in the bank or under stones. Thus we often find half a dozen brook-leeches clinging to the under surface of a flat stone; the water-vole has its bank-burrow; the lamprey grips with its circular suctorial mouth; the aquatic larvæ of many insects, like stone-flies, have grappling claws at the ends of their legs; the caddis-worms are often weighted with their encasement of agglutinated pebbles.

Animal Life in Rivers.

The second reason for the relative sparseness of the river fauna is to be found in the difficulty of securing the eggs and the juvenile stages from being swept down to the sea, or carried by a freshet into an unsuitable backwater. The female salmon flicks the gravel over her eggs, which are at once resilient and adhesive. Thus they are shut into crannies among the stones, and are also in some measure hidden from hungry enemies. The lampreys make a stone nest; the male stickleback fashions one of pieces of water-plant; the water-snail glues its eggs on to leaves. How very curious (and suggestive of difficulties) is the device of the bitterling, a little carp-like fish, common in some parts of Central Europe. It has a long egg-laying tube or ovipositor by means of which it introduces its few and large eggs into the shell-cavity of a freshwater mussel. Thence they are wafted by the action of microscopic cilia into the cavity of a gill-plate—a well-aërated cradle. After about a month's development, the young fry, nearly half an inch long, swim out of the mussel. But the mussel sometimes utilises the fish, just as the fish the mussel! The pinhead-like bivalved larvæ of the freshwater mussel develop in the early summer months inside the cavity of a gill-plate, and when a bitterling comes nosing about, towards midsummer, the fish liberates a crowd of larvæ which swim rapidly, snapping their toothed valves and secreting glutinous threads. Some succeed in attaching themselves to the skin of the bitterling, and are carried about for some time, undergoing a change of structure. At the end of this metamorphosis they drop off into the mud on the floor of the stream. In Britain, where there is no bitterling, some other fish, like minnow or trout, is similarly utilised.

We see, then, that juvenile life is not easy in streams. It is difficult in proportion to the velocity of the current. Thus, it is not surprising to find in most freshwater animals a telescoping of the larval stages, as may be illustrated by contrasting the freshwater crayfish and the shore-crab. In the latter the egg develops into a free-swimming larva, the zoæa, which leaves the shelter of the maternal tail and makes for open waters. It feeds, grows and moults, becoming a meta-zoæa; after a while it changes into a megalops; this ceases to be pelagic, and, sinking on to the floor of the sea, becomes a miniature crab, which creeps up the long slope to the shore. Here is a drawn-out succession of larval stages, but in the freshwater crayfish there are none. What come out of the eggs under the mother's tail are miniatures of the adult, except that the tips of the great claws are strangely incurved, the better to grip the empty egg-shells which are glued to the swimmerets. In this case there are three precautions: the eggs are carried about by the mother; there is a suppression of the riskful larval stages; and the young crayfishes remain for a time holding on to their mother's apron-strings.

A RIVER SCENE.

A picture of what may be seen on many a river—the overhanging branches of the trees on the bank, the rushes by the side of the stream, the various kinds of water-weeds, even water-lilies, growing in the quiet reaches.

Photo: Hugh Main.

THE FRESHWATER SNAIL (*Limnaea stagnalis*).

This little snail is to be found in almost any pond or river where water-weeds are abundant. It is a vigorous vegetarian. Often it may be seen gliding with its flat foot against a leaf, or floating shell uppermost in the water, or moving shell downwards below the surface film. Sometimes it seems to make ropes of its own slime. It is a lung-breather and fills its breathing chamber at the surface.

of our ponds is greatly developed in certain species of tadpoles that have learned to resist the torrential streams of the Himalayas.

A third difficulty in carrying on the business of life in a river worthy of the name is that the food tends to slip past with tantalising velocity. So is it when the tide ebbs on the shore, it carries with it thousands of spread tables. But there is this consolation on the shore that the tide will turn and bring back part at least of the banquet of microscopic dainties and débris. In the river, as the poet Burns remarked, what is lost is lost for ever. Now there are many ways in which fluviatile animals are able to make the most of a food supply that is always being hurried past; but what could be neater than the net-like snares made by some caddis-flies during the aquatic phase of their life. The mouth of the firmly fixed net faces upstream; it catches what is being swept past; and the caddis-worm has its own shelter beside the snare. Man utilises streams in the same way when he fashions fixed nets across them, but he does not surpass the caddis-worm in his artistry.

An objection might be raised against what has just been said by recalling the abundance of insect larvæ in many streams. Larval mayflies, stone-flies, caddis-flies, dragon-flies, and even some beetles seem to live very successfully in running water, and this is the more noteworthy since they evidently represent terrestrial or aerial animals that have secondarily returned to the freshwaters. But in all cases it will be found that there is some special adaptation which saves the larva from being borne down stream. Thus, there are six suckers on the ventral median line of some larval flies which actually frequent mountain-torrents in the Alps and Pyrenees; and the adhesive organ which we see on the newly hatched frog-larvæ

Photo: John J. Ward, F.E.S.

EGGS OF THE FRESHWATER SNAIL (*Limnaea stagnalis*).

The eggs are laid at intervals through the summer, and attached in clumps of about thirty to water-weed, each clump being surrounded by a curved mass of jelly about an inch long. The clump shown on the right has been recently deposited; the one on the left is older and shows the young snails developing. They hatch out in about a month; in three months the shell may be nearly an inch long; the full size is attained in about two years.

A fourth difficulty in the river is involved in the extremes of the seasons. In the dry season a strong stream may practically disappear, save for an occasional water-hole in its bed. This means a succession of evil days except for those river animals that are able to relapse into a state of latent life. Thus the African mudfish, Protopterus, which frequents marshes beside rivers, snuggles for more than a foot into the drying mud, and lies dormant for months, it may be for over half the year. It surrounds itself with slime, part of which keeps its skin moist, while the outer part hardens, along with adherent earth, into a cocoon. This has a lid, always with a small aperture which is continued inwards into a little funnel. On this the mudfish shuts its lips, and dry air entering by the pipe of the burrow passes directly to the lungs. For Protopterus is a double-breather or Dipnoan, with lungs as well as gills. For a fish out of water it does very well; but its life is almost at a standstill during the long rest and fast of the dry season.

More familiar to us is the extreme of prolonged frost, when the river is covered with a thick sheet of ice. To meet this difficulty, some of the active swimmers seek the unfrozen deeper parts, and there they profit by the almost unique property of water that it expands in freezing. For thus it comes about that the colder water rises to the surface, and during the hardness of winter the deeper zones of the water are rather warmer than those above. In summer they are colder, and this also works well. For some

Photo: F. W. Bond.

THE FRESHWATER MUSSEL (*Anodonta cygnea*).

This bivalve, often called the Swan Mussel, is four to six inches in length, two or three inches in breadth, and perhaps two inches across in maximum thickness from valve to valve. The colour of the shell is greenish-brown. Lines of growth on the shell indicate a possible age of twelve years.

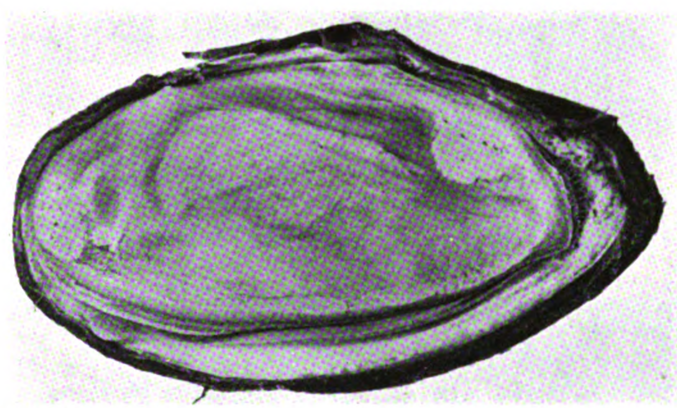


Photo: Hugh Main.

THE FRESHWATER MUSSEL, ONE VALVE REMOVED.

The Swan Mussel lives a leisurely life in the mud at the bottom of streams, and is sometimes fished for the sake of its pearls. The photograph shows the skin fold or mantle, the muscles that close the valves, and other features. The larvæ must sojourn for a while on a fish.

Photo: Hugh Main.

THE FRESHWATER MUSSEL, WITH MANTLE DISSECTED.

The Freshwater Mussel ploughs its way along in the mud by means of the very muscular foot, here shown. The photograph also shows the gills by which the mollusc breathes. The food consists of microscopic organisms in-wafted by the gills.

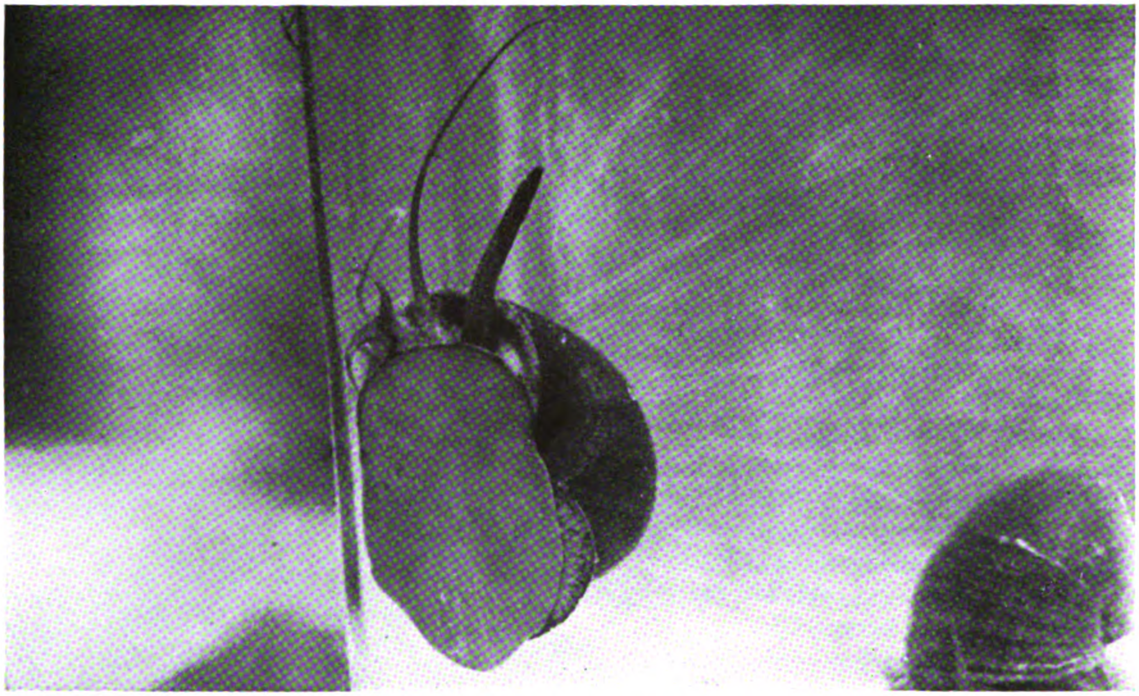


Photo: F. W. Bond.

THE APPLE SNAIL (*Ampullaria vermiformis*).

Amphibious snails of long pedigree, with a gill on the right side of the breathing cavity, and a lung on the left, thus making the best of water and air. The photograph shows the flat, creeping sole of the muscular ventral surface, or "foot," and the anterior end bears two pairs of long, tapering, sensitive tentacles and a long breathing-tube. Apple snails are common in Africa and South America; they are famous for their tenacity of life. The name "Apple" probably refers to the large glossy, somewhat globular shell.

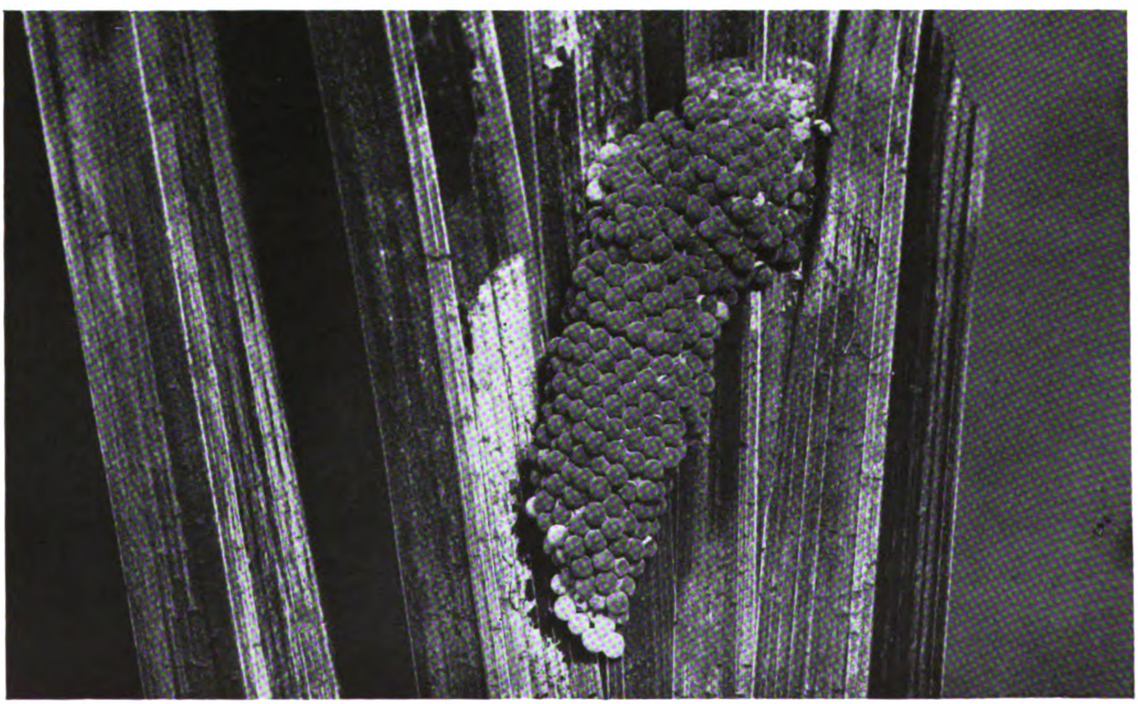


Photo: F. W. Bond.

EGGS OF THE APPLE SNAIL (*Ampullaria vermiformis*).

The eggs are laid in clumps on the stems of water-plants. They should be contrasted with the eggs of a big land-snail like Achatina which are as large as a pigeon's and have shells of lime. Those of Ampullaria are of good size, but without any shell; they are sought after by marsh birds.

river animals, however, the frost is fatal. They cannot live on as wholes but they survive in part. This is well illustrated by the freshwater sponges which form large growths in some rivers. As winter approaches they begin to die away, but they do not wholly die. In the moribund body there are formed pinhead-like clusters or nests of cells, called "gemmules," which are exquisitely encased in decorative capstans of flint. The encasement is so perfect that the cells within do not die. They survive the cold of winter and they develop into male and female sponges in the spring.

Children of the River.

As we have explained, rivers are difficult haunts of life, in proportion to the strength of their flow. There is often need for constant exertion, there is great danger of being swept away, food is borne quickly past, eggs and juvenile stages are liable to be carried down to the sea, the vicissitudes of the seasons are severe—such as an interrupted flow in summer and a frozen surface in winter. Thus, the river or fluviatile fauna is small compared with that in the other haunts of life—the lakes, the dry land, the shore, the open sea, and even the great abysses. But can we arrange in some orderly way the animals that are at home there?

First there are the conquerors, the supreme example being the hippopotamus. We saw one in the Zoological Gardens at Pretoria, ruddy with its peculiar blood-like sweat, about twelve feet long, impressive in its sheer massiveness. It plunged into its pool and yawned among the water-lilies. Whereupon a little Kaffir boy, seated on the parapet, shoved his foot into the giant's mouth and scraped the palate with the upper surface of his toes. It seemed to give mutual satisfaction, but we shuddered to think what would happen if the gaping mouth were to shut too quickly. There was no suggestion of ugliness in the hippopotamus; it seemed an artistic unity. We remembered our Job:

"See Great Behemoth with his ruddy hide
In the shade of the lotuses
Incircled by water-willows.
From the wild rushing torrent he flees not;
He is calm in the swell of a Jordan.
Behold now the strength in his loins,
And the force in the muscles of his belly.
His bones are as pipes of brass,
His limbs are like bars of iron.
He is the chief of the ways of God."

Among the conquerors nearer home a prominent place should be given to the otter, for, though it is half terrestrial, it is a strong swimmer and a neat diver, clever in its fishing, and defiant in its resourceful mastery of the river. Just as a seal may come far up a river, so the otter may swim far out to sea. It may seem absurd to call the beaver a conqueror, for it is becoming rarer every year, and it is long since there were any living wild in Britain. Yet it is to man, rather than to animal competitors, that the beaver has yielded, and it is still very plentiful in some parts of Canada and the Western States. As everyone knows, it is peculiarly a conqueror inasmuch as it acts forcefully on its environment. It is not content with things as they are, but makes dams and cuts canals. It circumvents the hard winter with its abundant stores of cut branches.

An interesting river animal, very inadequately known, is the West African Potamogale. It is an Insectivore, about the size of a stoat, with a very strong laterally compressed tail, which is used in rapid swimming in mountain streams. It probably feeds on water insects, which its long snout is well suited for catching. Among the conquerors must also be included such birds as the coot and the dabchick, such reptiles as alligators, crocodiles, and gavials, and such fishes as trout. Many turtles occur in rivers, but usually in backwaters or in pools without much flow.

The great Anaconda is an aquatic Boa, which combines arboreal and fluviatile life in a remarkable way, and this suggests another sub-group for those animals that spend only part of their life in the rivers. The salmon is a good example with alternation of freshwater and the sea; the flounder is the opposite, often going far up the rivers, but returning to the sea to spawn. Then there are the numerous insects, like dragon-flies, may-flies, stone-flies, and caddis-flies, which are fluviatile only in their larval stages.

A second group of river animals is that of the burrowers, well represented by our little Water Shrew (*Crossopus fodiens*). It swims gently on the surface, paddling with its feet, using the long tail as a rudder, and making hardly any ripple. It dives well and plays prettily in the water, but

Photo: Albert Henry Willford.

NEST AND EGGS OF THE COOT (*Fulica atra*).

The Coot's nest is built of flags, sedges, reeds, and rushes, among the vegetation by the side of the stream, or on a little island. If the water rises, the nest is added to, and we have seen a conspicuously high one on a rock in mid-stream. Six to ten eggs are laid late in April or in the beginning of May; the nestlings are covered with black down, but there is extraordinarily bright colouring—red, orange and blue—about the bill and head.

one could not group it among the conquerors. One could not say that it is " calm in the swell of a Jordan." It survives because it is a river-burrower. The same holds for the desman (Myogale) which used to occur in Britain, but is now restricted to the streams of the Pyrenees and some Russian mountains. It is another Insectivore, about five inches long in body, and as much again in tail. It has a very mobile snout, like the beginning of an elephant's trunk, which it curls round its booty of small river animals. It is said to be able to poke it into its mouth! The swimming organ is the laterally flattened tail, and with this there are associated strongly developed skin glands which make a secretion said to be repellent to the desman's enemies. We recall the odoriferous glands on the flanks of our common shrew, which have also a protective value. But the desman, suited as it is for mountain streams, would hardly survive if it did not make long burrows in the banks. In the same group we must rank the water-vole and the freshwater crayfish, good swimmers, of course, but likewise burrowers.

Along with the bank-burrowers may be included, for convenience, many animals which spend most of their life in the bed of the stream itself. Thus, there may be river-mussels, ploughing slowly in mud and sand, and there are various kinds of freshwater worms which are mostly confined to the substratum. They evade the problems of fluviatile life; they are in the river, rather than of it.

A third group should include all the grippers, which have some particular adaptation for holding on to stones and plants in the stream. A pretty example is the dipper or water-ouzel, which walks on the bed of the river, gripping with its toes, and helping itself along with its wings. We watched two of them for a long time

from a seat beside the river at Inverness, where the current was very rapid. Over and over again the bird flew into the water with the stream and emerged higher up against the stream. But sometimes it works downstream. In any case the dipper must be able to hold fast. It feeds on small animals, such as insect-larvæ, crustaceans, and molluscs; and it is for these that it scrutinises the bed of the stream so closely. The most interesting fact is that we have here to do with a relative of the wrens, which has taken to a semi-aquatic life in mountain streams, and has made a success of it. There are fishes that climb from stone to stone in torrents; there are mountain tadpoles with big adhesive organs; and in the same group come the leeches with their suckers, the slowly-moving river-limpet and the freshwater snails holding on by their flat sole, and a crowd of jointed-footed or Arthropod animals, like mites, insects, and crustaceans, that grip firmly with their claws. We can never forget the sight of freshwater snails crawling about nonchalantly on stones in the bed of the river a few yards from the edge of the Niagara Falls. It is certain that they could not spend their *larval* stages in that perilous habitat.

Besides conquerors and temporary tenants, burrowers in the banks and in the bed of the stream, and the crowd of creatures that survive because of their power of holding on, there are smaller groups of river-animals. In the Lochay at Killin, for instance, there are exuberant growths of freshwater sponge—a sedentary tenant, interesting because it undoubtedly represents a secondary colonisation of the freshwaters. There are scores of families of marine sponges, but only one family in rivers and lakes; therefore the inference is safe that the original home was in the sea. In some rivers there are great colonies of exceedingly beautiful freshwater Bryozoa, but few people notice them.

We must not leave the children of the river without calling attention to a very interesting fact, that many of them are "antiques." The

Photo: Capt. H. Morrey Salmon, M.C.

THE COOT SITTING (*Fulica atra*).

The Coot is a near relative of the water-hen, a heavily built, slate-grey bird, with a conspicuous white bill and white frontal plate, whence the name "Bald Coot." It is for the most part a resident bird in Britain, frequenting slow-flowing rivers, but sometimes visiting the coast in winter. It feeds on sappy water-weeds and on molluscs. It flies quickly but heavily; it dives continually but clumsily; it can swim well under water; it is very fond of a fight.

river is not an easy haunt, but when its difficulties have been overcome, it affords safe retreat. Thus some very old-fashioned types that have disappeared elsewhere remain in the sanctuary of the streams. For instance, the three mud-fishes or Dipnoi, Protopterus in Africa, Ceratodus in Queensland, and Lepidosiren in the Amazons, are what may be called "living fossils"—the only survivors of an ancient race. The European sturgeon and the North American Bony Pike are also very old-fashioned types; and the best examples of all are two fishes, Polypterus and Calamoichthys, from West African rivers, which are the only living representatives of an ancient order. We see, then, that a river may be a retreat—better than a museum!

The Beaver.

To Britain the beaver has long been a stranger; it lingers in only a few secluded corners in Europe; its range in North America is becoming more and more restricted. Its fur is all too good, and in spite of its shrewdness and sociality the beaver is not holding its own. Its relationship to squirrels is rather interesting, for both have left the original terrestrial life—the squirrels becoming (in their most typical representatives) arboreal, while the beaver has become specialised for aquatic life. Its strong, flat, scaly tail, which is used as a rudder, its webbed hind-feet, and its thick waterproof fur may be mentioned as conspicuous instances of adaptation to life in the water. In the summer months they often roam about for some distance from their settlement, but the heavy rounded body and the short legs cannot be regarded as very suitable for much locomotor activity on land.

When North America was first colonised there were beavers in great numbers from coast to coast; nowadays they have been pushed westwards and their ranks thinned. But this is for the most part due to man and the value he sets on the thick, silky under-fur. Apart from man the beaver would continue to prosper, for it has many safety-giving qualities. There is safety in swimming and diving, in making tunnels and stores, in working mostly at night, in living socially and using danger signals, and in having a fairly long bill of fare in addition to twigs and bark. But the main source of safety is in their wits, for although they belong to the order of rodents, not generally marked by high mental development, beavers have undoubtedly a plastic intelligence.

First of all there is the felling of trees which are often up to sixteen inches or so in diameter. With the chisel-edged front teeth the beaver cuts two parallel furrows across the grain of the wood, and then wrenches off the chip between. This is repeated laboriously many times till a biconical or hour-glass-like cut has been made all round the tree, which then falls. A careful observer records a case where a cotton-wood tree nearly thirty inches in diameter had been felled so skilfully that it tumbled with its top in the middle of a small beaver-pond, thus assuring abundance of food for the animals at their very door. But things do not usually happen so perfectly. Trees under a foot in diameter are preferred; there is often considerable labour of transport of cut branches from the tree to the lodge. Moreover, beavers seem often to tire of a tree and leave their work half done. We must, alas, surrender the pretty stories about the beaver-woodmen cutting the tree unequally so that it must fall to one chosen side; and it is extremely doubtful whether they ever intentionally leave a tree partially cut through to be brought down by the next gale.

Another line of activity is making the pond and its dam. The meaning of this is to have round the lodge conveniently deep water which will not freeze too deeply in the winter. The dam is made of drift-wood, willow branches, and the like, carried in the mouth, and the framework is strengthened by mud and stones which the beavers carry by pressing their hands against their breast. It is, of course, all nonsense that they use their flat tail as a trowel. The dam is usually a narrow affair, but streams of considerable breadth are sometimes stemmed, and the barrier is said to be built straight if there is almost no current, but with a convexity directed up-stream when there is a considerable flow. It is readily intelligible that some of the branches used in making the dam may eventually grow into bushes, so that the construction becomes hidden in green. There is some reason to think that beavers may have got the idea of the dam from naturally formed barriers of drift-wood such as one often sees in streams. Animals are more likely to adapt than to invent.

Specially drawn for this work by Roland Green, F.Z.S.

DRAGON FLIES HAWKING ABOVE THE POOL.

The larger Dragon fly in this drawing is *Æschna cyanea*, one of the most striking British species, finely coloured in blue, green, and yellow, very powerful on the wing, often rising to a height, with magnificently developed eyes showing over 20,000 lenses. The smaller species is *Calopteryx virgo*, blue bodied in the male, green bodied in the female, with blue wings in the male, greenish brown in the female. The eyes are far apart, not touching as in Æschna. The flight is fluttering.

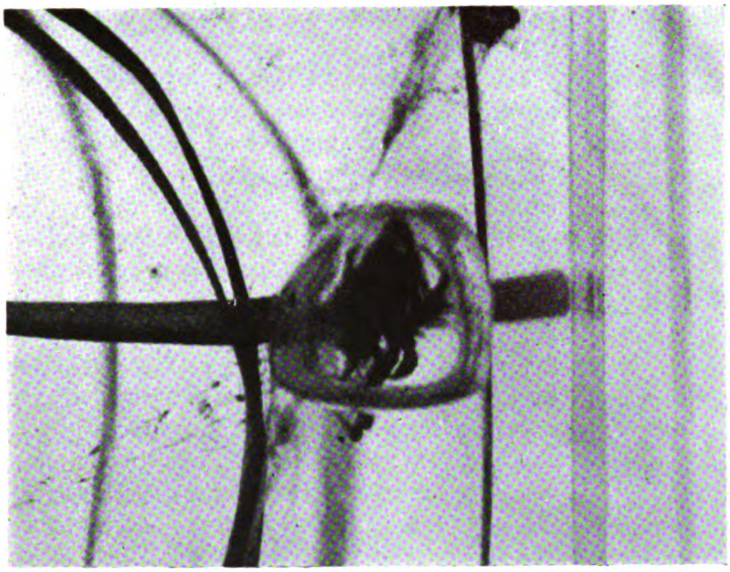


Photo: F. W. Bond.

WATER SPIDER (*Argyroneta aquatica*) IN AIR BELL.

The silken tent or bell is sometimes fastened to water-weed, sometimes to the floor of the pool. It is filled with air entangled in the spider's hair. It may be used as a shelter in the winter when Argyroneta lies very quiet; it is also a cradle for the eggs and young.

construction than is suggested by the pictures in the older books.

Where a beaver village is well established there must be a gradual reduction in the number of available trees. Those nearest the pond will be used first; but in the course of time little journeys will have to be made. The difficulties of transport will increase; hence the usefulness of canals, and the best of these are certainly remarkable. They may be several hundred feet long; they may form a short cut from one bend of a meandering stream to another; they may cut right through an island. A case like the last is particularly interesting, for the co-operative work would not have much justification until it was completed, with an open waterway right through. As in regard to the dams, so here we may venture the suggestion that in flat ground near a stream there are often approximations to natural canals in which the beavers may have found a hint or a basis for elaboration.

Two types of house are made by beavers, and there are many transitional forms. In rivers like the Colorado, with high banks and variable water-level, a tunnel well under water leads to a big burrow in the bank. The other type is the "lodge," a roughly conical erection of sticks and mud, several feet high, eight to ten feet across the base. The entrance is usually under water, or there may be two entrances. Part of the lodge is a living-room and bed-room, the rest is a store. But twigs and branches are sometimes stored beside the house on the floor of the pond, being weighted down with stones and mud, a device that certainly smacks of intelligence. Another interesting point is that extra mud is often pressed in the autumn on the outside of the house, with the result that it forms when frozen hard not only a comfortable wall, but an effective protection against the intrusions of wolves and wolverines. But it need hardly be said that the beaver's lodge, even at its best, is a much rougher

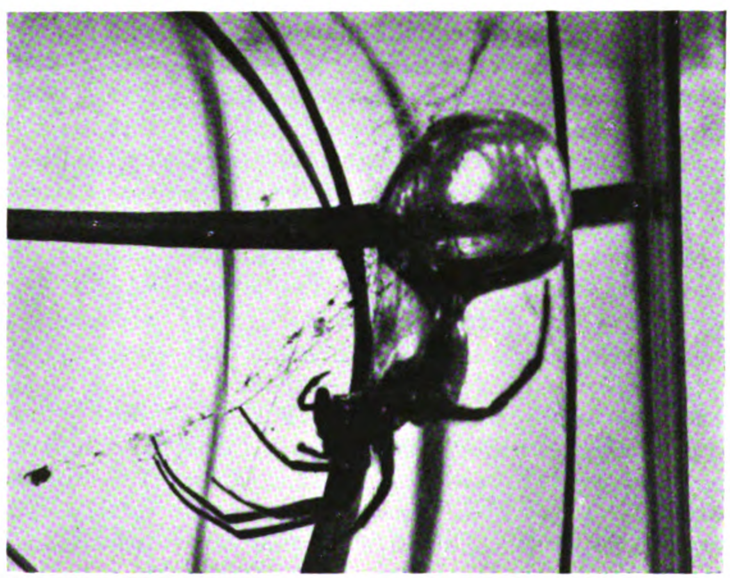


Photo: F. W. Bond.

WATER SPIDER (*Argyroneta aquatica*) LEAVING AIR BELL.

The air that is captured at the surface of the water in the capillary spaces between the hairs or setæ of the body is brushed off inside the silken tent or bell. It is this air that the young spiders, hatched in the bell, utilise for their breathing.

The beaver is monogamous and affectionate, with a prolonged youth and pleasant family relations. It has the co-operative temperament, and its sociality has doubtless promoted its intelligence. This works in a circle ; it takes a certain fineness of brain to be social, as distinguished from merely gregarious ; and in the developing animal-society there is a selecting or sifting process which favours variants in the direction of wits on the one hand and self-subordination on the other. The American beaver and the European beaver are very closely akin and the wide range of geographical distribution—until man intervened—is an expression of Nature's approval of a sagacious and social creature.

Story of the Dabchick.

It is certainly a great privilege to live near a river where one can see dabchicks, or Little Grebes, disporting themselves. Not that one can see them whenever one likes, but they are oftener to be seen than a casual visitor would think. They are dainty, compact little birds, about nine inches long, with almost no tail. Their colouring makes for inconspicuousness, dark brown above, greyish white below, and a little paler on the whole when winter comes. There is an intense pleasure in watching dabchicks, their movements are so vivacious. They are artists in self-effacement, for not only are they continually turning somersaults and diving, but they have got some other way of *simply disappearing*. How this vanishing trick is done we do not know. And even the diving movements are so quick that the eye can hardly be sure—even after a hundred observations—of what actually happens. The bird raises its body vertically out of the water, turns a somersault, and goes down head foremost ; but our words are too terribly clumsy for the marvellous gymnastic feat. Under water, dabchicks swim deftly with their " chestnut-leaf " feet, the lower leg showing a remarkable swivel-like adjustment ; but Macgillivray may be trusted in his observation that they also use their wings. Like some other aquatic birds they fly in the water. Everyone knows that the dabchicks often reappear very quickly a long way from where they disappeared, so the locomotion under water must have a great speed. If this grebelet uses wings and feet at once it is almost like becoming a quadruped again, for the ancestors of birds were reptilian quadrupeds.

Dabchicks frequent lochs and ponds and the slow-flowing reaches of rivers, and they are found from the high moorland to the shore. In the winter, when the lochs may be partly frozen, and when small water animals are scarce, they often come to an estuary, which they enliven with their pretty ways, or they may frequent the lagoons of a seashore marsh. Except in so far as a few come to Britain in winter from further north, and in so far as many of them move from one part of the country to another, dabchicks may be called resident birds in this country. They do not readily take to wing, but when they do they fly at a great speed and very straight. It is rather a surprise to find that they can also run quickly if hard pressed.

The food of the Little Grebe consists of aquatic insect-larvæ, water snails, little fishes, and a salad of weeds. It is the comparative minuteness of the items on the bill of fare that makes the incessant diving necessary. For many birds it is a case of " many a pickle making a mickle."

Little is known in regard to the courtship of the dabchick, which is a pity if it even approaches that of the Great Crested Grebe, so carefully studied by Prof. Julian Huxley. The mating birds call to one another cheerfully, saying whit, whit ; and they work together in building a rather large nest. This may float, attached to rushes, or it may be firmly moored to a branch that has fallen into the loch, or it may be built up from the bottom in shallow water. In any case, the nest is constructed with a large margin of safety, so that the saucer-like hollow in the middle is always well above the surface of the water. It is adjusted so that the water does not reach the eggs, or the brooding bird, or the nestlings. That would be fatal.

The nest is made of water-plants, and as they die they ferment, thus raising the temperature—all the better for the development of the eggs. The warmth of the decomposing plants makes it easier for the brooding bird to take an occasional holiday, and, as a matter of fact, the two parents may be seen gaily playing together while the eggs are being incubated in the warmth induced by the activity of Bacteria ! For there is no rotting without Bacteria. When the precious

Photo: H. Morrey Salmon.

MALE OF THE LITTLE GREBE, OR DABCHICK, SITTING.

The smallest of the Grebes, *Podiceps fluviatilis*, is a resident or partial migrant bird in Britain, and common in Europe, Asia, and North Africa. The nest is a large mass of water-weeds and is usually floating. Both parents share in the brooding.

Photo: Albert Henry Willford.

LITTLE GREBE APPROACHING HER NEST.

If a brooding Dabchick has to leave its eggs in the nest, it usually conceals them with great rapidity by drawing some of the nesting material on to the top of them. The eggs, 4–6 in number, are white to begin with, but they soon become stained.

nest is thus left to itself, a blanket of weeds is very rapidly drawn over the four to six white eggs. Both parents build and both parents brood; and there are two clutches in the year, between April and August. The eggs, like those of other grebes, are biconical, the two ends being almost or quite alike. They have a chalky shell, and this gets stained by the damp weeds on which they rest, so that after the first week or so the clutch of eggs becomes almost invisible.

The nestlings are attractive little creatures with black down changing gradually to brown, and reddish harlequin-like or agate-like stripes changing gradually to white. The young ones are fed by both parents, and their education begins early. The mother or the father takes them for a little voyage, and they hold on to their parent's back. When the parent bird submerges its body the youngsters have perforce to swim. If there is some danger, the mother keeps the young ones under her wings, and may dive with them in that position. We read that when they are resting on the nest under their mother's wings they poke out their heads in a winsome way when the father approaches with food in his mouth. We hope to see this some day. When the young dabchicks have found expression for their diving and swimming instincts, and when they have learned some lessons about food and enemies, they may still be seen swimming about with their parents. But some day there is a big alarm, the family party breaks up and the youngsters scatter, never to come together again. The "apron-strings" are cut.

When we ask how this attractive bird, which Ruskin called "our little living ripple-line of the pools," holds its own to-day, we find the answer first of all in its minute size. It is one of the "little people," easily overlooked. Its colouration also makes for self-effacement. Moreover, it is a singularly quiet bird; for, as Professor Newton points out, "it often happens that a pair will frequent a small weedy pond, nigh unto a human habitation, and rear their young there, without their existence being detected, though they stay for the whole of a summer." Thirdly, there must be safety in their extraordinary

alertness; it is almost impossible to take a dabchick by surprise. But a bird may be alert and yet not quick to move, as is plain in the case of geese. So to alertness the dabchick has added quickness of reaction. They disappear "like a shot," fortunately often quicker than the shot. The reappearance somewhere else is also a good life-preserving trick. We are not forgetting that the dabchick has a fairly large family and that the youngsters are well educated, getting a good send-off in life, but in the main the bird survives because of its alert elusiveness and its rapidity of action. Ruskin talks a good deal of nonsense, we think, in his account of the dabchick in "Love's Meinie," but he was perhaps right in calling it "the prettiest bird, next to the kingfisher, that haunts our English rivers." Who can help wishing "Long life to the Dabchick"?

Among freshwater animals it is strange that we have to include a lung-breathing lizard. But unexpectedness is one of the charms of Natural History. As Goethe said, animals are continually attempting the next-to-impossible and achieving it! Partly, no doubt, the struggle for existence supplies the spur; but in higher animals there is also the prompting of the spirit of adventure. Animals are always on the look-out for a new niche of opportunity, and thus we find the unexpected often happening. What is a lung-breathing snake doing in the sea a hundred miles from land? What is such a terrestrial animal as a spider doing in a pool on the moorland where she weaves a sub-aquatic dome of silk and fills it with dry air? How comes an Amphibian like the blindworm, or a bird like the burrowing parrot, to be living beneath the ground? Or, to come to our present point, what is a lizard doing in the water?

Ways of the Water-Lizard.

Reptiles were the first backboned animals to become quite at home on dry land, thus completing the great transition which was begun by their amphibian ancestors. But not a few of them have in the course of time retraced their steps and gone back to the water, lung-breathers though they be. Thus there are crocodilians, turtles, and sea-snakes that we may call

Photo: Albert Henry Willford.

LITTLE GREBE APPROACHING HER NEST.

In this case the mother-bird was intentionally disturbed so that she had to leave the eggs uncovered. But this is quite unnatural. The young birds can dive as soon as they take to the water, but they often get education-rides on the parent's back.

Photo: A. W. Dennis.

THE BOG BEAN (*Menyanthes trifoliata*).

This is one of the most beautiful of the bog-plants, growing in pools in North Temperate countries, including Britain. It has luxuriant aerial leaves rising from a creeping submerged stem, and the flower-stalks, bearing clusters of white blossoms, also rise above the water. It belongs to the Gentian family.

" secondarily aquatic." In the lizard order of reptiles, however, the terrestrial habit, including burrowing and tree-climbing, is so strong that exceptions are of great interest; and we wish to refer to the story that Dr. Ph. F. Kopstein has recently told of the " water-lizard " of the Moluccas. It is not a new animal by any means, but little has been previously known of its habits, which are certainly peculiar. Its name is Lophura, and the best known kind or species, living in Amboina, Ceram, and Celebes, is *Lophura amboinensis* which Dr. Kopstein has studied. There is another kind in Ternate and Halmahera, and a third is at home in the Philippines. This suggests the rôle of isolation in fixing new departures into new species, as we know nearer home in the Orkney vole and the St. Kilda wren. In mankind, likewise, some form of isolation, narrowing the range of marriage, seems to have been a frequent factor in fixing racial traits.

The water-lizard or " hydrosaur " of Amboina never goes far from the water; it stretches itself on branches overhanging streams, ponds and lagoons, and dives if violently disturbed. The same individual comes back to the same branch day after day and lies there almost imperturbable. For it has no enemies — not even man. Apart from two kinds of civet, there are no beasts of prey in the Moluccas, and the natives do not eat the water-lizard. This explains the imperturbability of the adults.

It is very different with the young ones, however, for they are quick to hide themselves under stones in the bed of the stream or among thick vegetation in the pool. The reason is plain; they are persecuted by herons and hawks until they reach their adult strength, when all their shyness disappears. No wonder, for they are over two feet long! As for their own food, it consists exclusively of the leaves and other parts of plants growing in, or beside, the water. Dr. Kopstein found a number frequenting a pool in which there were several warm sulphur springs, but he never saw one in the sea. So it remains true that the only marine lizard is the seaweed-eating Amblyrhynchus of the Galapagos Islands.

The eggs are buried eight to twelve inches deep in the fine river-sand at well-warmed spots where there is some stability. For just as our

hen-salmon avoid depositing their eggs among shifting gravel, so the hen-hydrosaurs avoid shifting sand. Although the natives do not eat the adults, they are fond of the eggs, which have relatively large yolks and are said to be very palatable. They are worth searching for, since they reach a length of over two inches. They are enclosed in firm parchment-like "shells," dirty white, with grey spots and streaks. An interesting point is that hatching goes on all the year round, which puzzles us till we remember that the Moluccas have a climate almost without seasons.

Apart from habits, the most striking feature of the water-lizard is the tail-crest of the mature male. It rises like a sail along the dorsal middle line of the caudal region and gives the creature a very striking appearance. There is no doubt that it is a masculine exuberance, like the growth of antlers in a stag; and a notable fact is that it does not appear till the male is full-grown and lusty. A male two feet long is exactly like the female, but after that it unfurls its sail, probably with the help of a chemical messenger or "hormone" carried through the body by the blood. It seems very appropriate that a lizard that has taken to the water should have developed a sail; but this is only a coincidence, as is shown by its restriction to one sex.

Concerning Dragon-Flies.

As long ago as 1883 the French entomologist Amans suggested that hints for electrical flying-machines might be got from dragon-flies, and one of the first successful French types of monoplane was called the "Demoiselle," which is also the name of the dragon-fly. One cannot, indeed, watch the larger dragon-flies "skimming" over the water without thinking of aeroplanes, and Mr. R. J. Tillyard, who has written a fine "Biology of Dragon-flies" (Cambridge, 1917), says that "a study of the different effects on flight of angulated and rounded hind-wings, as well as of the arrangements of braces and cross-pieces suggested by various parts of the dragon-fly's wing, might well lead to further improvements in our models, and might even suggest a solution for 'hovering' on simpler lines than anything yet attained." Actually,

Photo: A. W. Dennis.

THE YELLOW IRIS (*Iris pseudacorus*).

The yellow flag or Iris is a very beautiful wildflower, in damp places near water; and there are many other wild species as well as cultivated varieties derived from them. There is a creeping stem from which sword-like leaves ascend. A remarkable feature is that the styles of the flower have taken on the form of petals. Bees effect pollination.

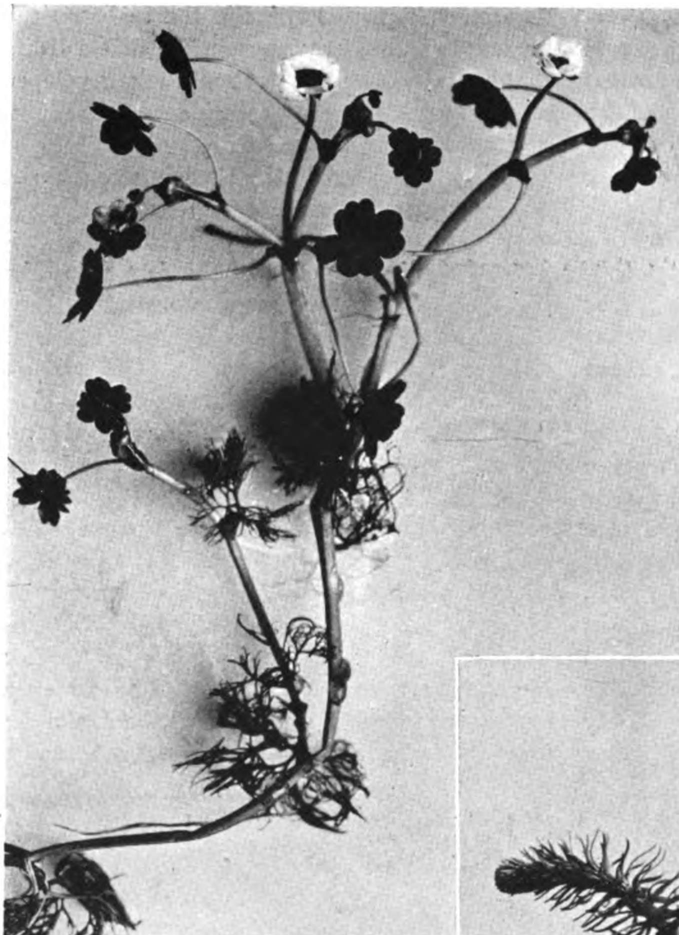


Photo: John J. Ward, F.E.S.

THE WATER BUTTERCUP (*Ranunculus aquatilis*) SHOWING FLOATING AND SUBMERGED LEAVES.

The floating leaves are simply lobed, but the submerged leaves are much divided into almost thread-like parts. According to the nature of the current will be the proportion of lobed and cut-up leaves.

since 1917 many improvements have been made. It is understood, of course, that the wings of dragon-flies strike the air, and that with almost incredible rapidity of vibration, while "planes" do not.

As we see dragon-flies hawking over the pond, darting up and down the stream, sailing over the moor round the "lochans" where they were born, we recall Tennyson's phrase, "a living flash of light." The gauze-like, never folded wings, the conspicuous eyes, the metallic sheen of the armature (Tennyson's "bright plates of sapphire mail"), the long, narrow posterior body, the baffling rapidity and sure poise of the flight, and the mysterious way in which many of them disappear and reappear as they fly around us, combine to make them unusually attractive insects, though one of their many popular names, "Devil's Darning-needles," is scarcely enthusiastic. In spite of another name, "Horse-stingers," they do not sting, and they are almost altogether beneficial as far as man is concerned, for they wage effective war against flies and gnats and other troublesome insects. Mr. Tillyard caught one with its mouth so full of mosquitoes that it could not be shut. "There must have been over a hundred, all tightly packed

Photo: E. Step, F.L.S.

MARE'S TAIL (*Hippuris vulgaris*).

This graceful water-plant has a creeping stem, from which upright shoots rise half out of the water. These bear leaves in whorls, with a far-off suggestion of horse-tails, which are not flowering plants at all. There is an interesting contrast between the under-water and above-water leaves.

into a black mass." It is suggested that the mosquito pest in the ornamental waters of parks might be checked by introducing suitable dragon-flies, whose larvæ as well as adults would prey upon the nuisance. A "glorious red" species has become well established in the Botanical Gardens at Brisbane, "and certainly adds a vivid touch of colour to its lovely surroundings."

The flight of dragon-flies must be near perfection; it is sometimes a sequence of lightning-like jerks, sometimes a regular swift sculling close to the water, sometimes a zigzag spiral ascent in the air, sometimes an even easy skimming "through crofts and pastures wet with dew." There is a remarkable peculiarity in the direct way the numerous muscles of flight are connected with the wing-bases; the velocity may rise to nearly sixty miles an hour; the two pairs of wings work quite independently, yet harmoniously. For some distance, like a wasp, a dragon-fly can fly tail foremost. They do not usually wander far from their favourite haunts, but some species with a migratory bent may travel hundreds of miles. An Australian form, *Hemicordulia tau*, has recently colonised Tasmania, across a strait two hundred miles wide. The perfection of flight is connected with the habit of catching insects on the wing, and with this also we associate the very mobile head and the high development of the eyes, both

Photo: E. Step, F.L.S.

SHINING PONDWEED (*Potamogeton lucens*).

There are a great many different kinds of Pondweeds all over the world. They have creeping stems and erect leafy branches, but some of these may be always submerged as in *P. lucens*, while others spread out many of their leaves flat on the surface, as in *P. natans*. The above water flowers are pollinated by the wind.

Photo: E. Step, F.L.S.

REED-MACE, BULRUSH OR CAT'S-TAIL (*Typha latifolia*).

The lower part of the bulrush stem is a thick submerged rhizome; the upper part projects high into the air. The naked flowers form a crowded spike, with yellow male flowers above and brown female flowers below. The pollination is effected by the wind.

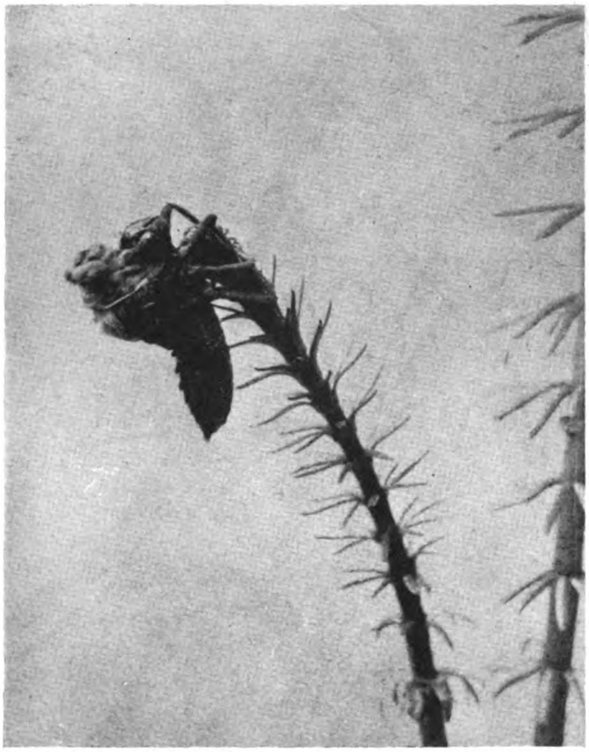


Photo: John J. Ward, F.E.S.

1. EMERGENCE OF A DRAGON-FLY (*Libellula depressa*) FROM THE NYMPH CUTICLE.

This kind of Dragon-fly has a rather broad body, which is blue posteriorly in the male, brownish-yellow in the female. The larvæ, which are found in stagnant water, and the nymphs which creep out of it, are unusually broad and squat in body.

reminding us of birds. The sense of smell seems to be practically absent; the sense of hearing is probably represented by a sense of poise; taste and touch are as in many other insects, but vision is probably the keenest among backboneless animals. The number of facets and lenses and other eye-elements in each compound eye varies from 10,000 to 28,000; and the range of vision, as far as the detection of movements is concerned, is up to 10–20 yards, the limit for other insects being about six feet. "When a dragon-fly is caught and held in the hand the eyes are seen to glow with a most beautiful light, generally of a semi-metallic green or blue colour, sometimes red, brown or grey. This is a reflection of light from the interior of the eye, and is called the *internal light*."

Dragon-flies have fine brains, and they are as clever as is good for them. When a large one has been accidentally decapitated the rest of the body may for a couple of days flutter its wings and even climb up curtains with its legs. This points to remarkable independence in the nerve-centres (or ganglia) of the ventral nerve-cord, and does not bear on the question of intelligence, any more than does the fact that if the terminal rings of a large dragon-fly be snipped off and presented to the head, they will be devoured "with apparent relish." We are misunderstanding the dragon-fly badly if we imagine that it ever "knows what it is eating"!

As regards body-colouring, dragon-flies deserve a first place among insects, though they are excelled by butterflies if the wings are taken into account. Various coloured materials or pigments are deposited in the cuticle and skin in the form of granules, and there is sometimes an exudation of pigment on the surface, like the bloom on ripe fruit, when the insect is becoming mature. "Interference colouration," such

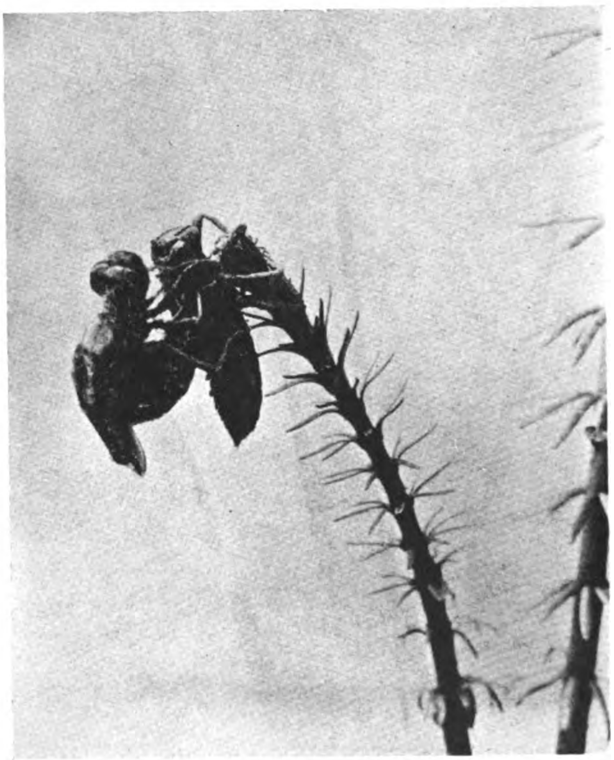


Photo: John J. Ward, F.E.S.

2. THE DRAGON-FLY WITHDRAWING ITS TAIL END.

It is a delicate business this, drawing the fully-formed body of the imago out of the nymphal husk. The excellent photograph shows the moment when the Dragon-fly is almost free—all but the tip of the tail.

Photo: John J. Ward, F.E.S.

3. **IT BEGINS TO SHOW ITS WINGS.**

After drawing itself out of the nymph cuticle, the fully-formed Dragon-fly begins to expand its wings, which were gradually developed, though not liberated, in the nymph stage.

as we see on a soap-bubble, is very common, and when it is combined with "pigmentary colouration" the result is often extraordinarily brilliant. Green, blue, violet, purple, red, orange, yellow, and other colours are displayed in exuberance, suggesting that their possessors do not need to be afraid of self-advertisement. In some larvæ there is evidence of a slow power of colour-change, in harmony with the hue of the surroundings.

It is doubtless because of their beauty and graceful movements that what we call dragon-flies are elsewhere called "demoiselles," "Wasserjungfer," or the like (so much depends on the point of view); but it is interesting to note that except in the sub-family Æschinæ the females are seldom seen flying upon the water except when pairing or laying the eggs. The males are the conspicuous demoiselles; the females seek cover among grass and herbage. There is often a sort of courtship, in which the males dance in the air before their desired mates and show off some of their good points. The male of one species waves a pair of white ribbons to attract the female's attention. There is occasionally a miniature *pas de deux* (a dance for two persons) before pairing.

The eggs may be laid in little holes cut in the stems of iris, reeds, or even osiers, or among the roots of mosses growing on damp rocks, or in firm, gelatinous ropes entangled on submerged twigs; but in most cases the female skims over the quiet or flowing water, and touching the surface now and then with the posterior tip of her body liberates masses of eggs, surrounded with jelly. The gelatinous substance dissolves in the water and the eggs are scattered about on the bed of the river or on the floor of the pond. Out of the egg-shell there emerges a "pronymph" which grows very rapidly for a few seconds or minutes, and then, moulting its cuticle, becomes a wriggling free-swimming larva fully equipped for the

Photo: John J. Ward, F.E.S.

4. **THE WINGS SHAKING OUT FROM THEIR FOLDS.**

The wings are soft and crumpled at first; they are hollow bag-like outgrowths from the two posterior rings of the thorax; they expand when blood is forced into them. The story continues overleaf.

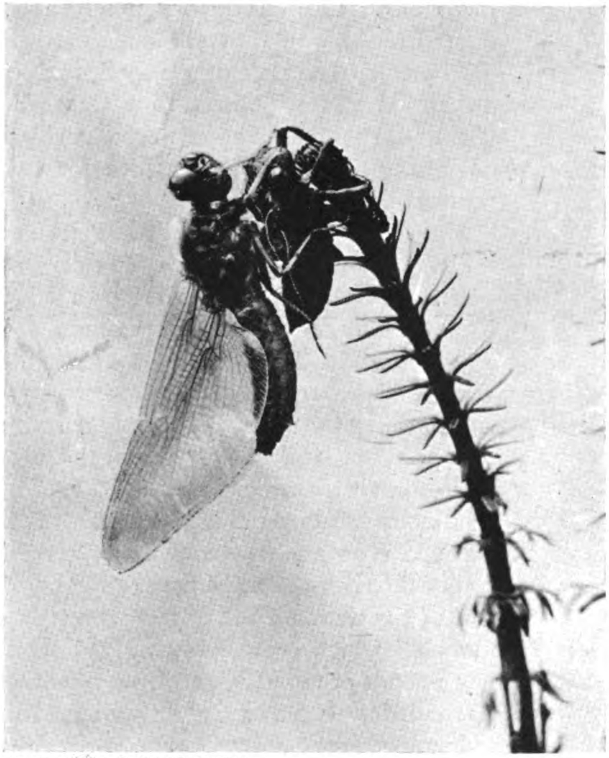


Photo: John J. Ward, F.E.S.

5. IN FIVE MINUTES THEY ARE FULLY EXTENDED.

The expansion of the wings, as the blood is pumped into them, is accompanied by a hardening of chitin along the the lines of the so-called veins.

bread-and-butter part of the business of life. The larvæ live under water for about a year, or, it may be, for as many as five years. They are extraordinarily voracious, eating almost any kind of small living animal from Protozoa upwards, and even attacking tadpoles. Mr. Tillyard starved one for a week and then gave it mosquito larvæ, sixty of which it swallowed within ten minutes. "After that," we read, "nothing would tempt it." The larvæ are given to cannibalism within their own order, and are sometimes seen stalking their own near kin.

The most remarkable larval characteristic is the protrusible food-catching "mask," so-called because it hides the other mouth-parts or even the whole face. It consists of the third pair of mouth-parts (labium) fixed on the end of a jointed hollow stalk. When the victim is within reach the mask is shot out with great rapidity, two sharp hooks fix themselves automatically in the booty, and after the struggles become less violent the mask is drawn back to its position of rest beside the mouth, where the first pair of mouth-parts (the mandibles) begin the work of chewing.

The respiration of the aquatic larvæ is also very interesting. Water passes into and out of the terminal part of the food-canal, which is often furnished with a beautiful "branchial basket." When the water is driven out forcibly the larva is jerked forwards, so that the functions of breathing and locomotion work together. Many of the larvæ have also got thread-like or plate-like tracheal gills, as in Mayflies. The air captured from the water is carried to every hole and corner of the body by means of branching trachæ or air-tubes, which are characteristic of all insects, but the stigmata or openings of these tubes, which are wide open in the Adult dragon-fly are either closed or of very

Photo: John J. Ward, F.E.S.

6. THE DRAGON-FLY ASSUMES ITS NATURAL RESTING ATTITUDE.

It may take half an hour or so for the wings to be stretched; but it may be three hours before the wings are quite dry and firm, and outstretched as shown, at right angles to the body. Then the insect is ready for flight.

slight importance in the larva. Had the tracheæ wide openings as in the adults, the larvæ would drown.

During the long larval life many changes occur: the facets of the compound eyes increase in number, the simple eyes make their appearance, the feelers get more joints, the beginnings of the wings are formed, and the thorax changes as they develop, and at intervals—from eleven to fifteen times—there is a thoroughgoing moult or cuticle-casting. This means not only shedding the covering of the body (Tennyson said : " An inner impulse rent the veil of his old husk "), but a surrender of the lining of the air-tubes and of the foremost and hindmost parts of the food-canal. As we have explained in the chapter on life-histories, this moulting is the tax that the creature has to pay for its armour, which, being without living cells, cannot grow, and is always becoming too small for the creature inside.

After prolonged internal changes towards the architecture of the adult, the great change or metamorphosis occurs. The larva becomes listless and loses its appetite, it changes its colour and appears tense and swollen—it is manifestly out of sorts. It climbs or crawls out of the water and fixes itself firmly to a reed or some other support. It arches its back and its cuticle splits along the mid-dorsal line, it gets its head and thorax free, it draws its legs and wings out of their sheaths, it hangs head downwards and its limbs harden, it waves about and succeeds in jerking itself upwards again, it holds fast to its support and withdraws the tail from the larval husk ; it drives blood into the crumpled bag-like wings and expands them. The presence of blood in the wings produces a peculiarly beautiful iridescence, which lasts for hours or days till the wings dry. The favourite time for the remarkable metamorphosis, which Réaumur described with great perfection about 1740, is at or near dawn.

Dragon-flies must have had a long pedigree, for in the Upper Carboniferous epoch they had many fine representatives, including the truly magnificent *Meganeura monyi*, which had a spread of wing of about twenty-seven inches, far exceeding that of any living insect. Since these ancient days, which were not, of course, near the beginning of dragon-fly history, the order has occupied a singularly isolated position, having no near relatives. Thanks to their powerful baffling flight, their keen, long-sighted vision, their carnivorous habits, their inconspicuousness when resting, and other qualities, dragon-flies have a strong grip of life, and long may it last.

Photo : E. Step, F.L.S.

HINGED MASK OF THE DRAGON-FLY LARVA (*Æschna cyanea*).

In insects there are three pairs of mouth parts—the mandibles, the first maxillæ, and the second maxillæ. The last pair, taken together, form the "labium"; and the extraordinary "mask" of the dragon-fly larva is a transformed labium. It is a "lip-arm" of three parts with two curved teeth at the tip, well shown in the photograph. It can be rapidly thrown out and as rapidly retracted, with a tadpole or the like in its grip. There are few more effective instruments.

They are represented all over the world by more than 400 genera, with about 2,500 species—a testimony to success ! But they have their enemies. Kingfishers are expert in catching them ; spiders snare them ; lizards and snakes snap them up ; the giant sundew of Australia takes heavy toll. The aquatic larvæ are devoured by their own relatives, by the young of the water-beetle Dytiscus, and by trout.

Very striking is the habit of *Polynema natans*, one of our " fairy-flies " (tiny Hymenoptera), which uses its wings for swimming under water and lays its eggs inside the eggs of a dragon-fly

deposited in the leaves of water-lilies. The grub of the fairy-fly hatches out in the dragon-fly's egg and devours it in a few days. Mr. Tillyard, to whose fine book on "The Biology of Dragon-flies" we are greatly indebted, notes that the most deadly enemy of full-grown dragon-flies is the trout; and here man has his thread in the web of life. In Tasmania the introduction of the English trout has reduced the dragon-fly fauna to a minimum. A two-pound trout, caught by Mr. Tillyard on the Macquarie River, in Tasmania, had in its stomach the undigested heads of thirty-five dragon-flies. But this means that injurious pests like scale-insects will increase.

The Story of Mayflies.

On the stones or among the weed in the river, one often sees, in the summer time, a number of wriggling flattish creatures, with three pairs of legs, with two or three filaments at the tail end, and with a double row of delicate platelets—the breathing organs or tracheal gills—on the posterior part of the elongated body. Some of these wriggling creatures are young Mayflies, though there is not much about them that suggests the delicate adult insects which rise in living clouds from the quiet reaches of the stream in the end of May or in the beginning of June. Day-Flies or Ephemerides they are called because of the shortness of the winged chapter in their life-history. It may not last more than a day. Indeed, there is one case known where the aerial life lasts only for an hour! Yet we are apt to misunderstand the Mayfly story unless we get firm hold of the fact that it is only the winged part of the life that is so very short. Many of them have an aquatic life of two or three years, so they are not such short-lived creatures after all.

There is a useful Natural History idea here, that we spoke of in connection with Life-Histories, namely, that different kinds of animals lengthen out or shorten down different stages in their life-cycle. Some animals have a very short youth, a long period of full-grown strength, and a rapid end; others have a short period of intense vigour and a long drawn-out decline, as happens sometimes among mankind. What do the Mayflies show? They have a very prolonged juvenile life beneath the water, a greatly reduced period of maturity as winged insects in the air, and then an abrupt death.

The larvæ or nymphs of the Mayflies are suited in many interesting ways to the conditions of their life. They absorb the oxygen in the water by means of the delicate "tracheal gills" on the back of some or all of the first seven segments of the so-called "abdomen." The long tail-filaments may also help in this breathing, for what always happens is that oxygen seeps into the internal air-tubes or tracheæ which penetrate into every hole and corner of the body. The tracheal gills are sometimes neatly protected by a cover and by interlacing fringes of bristles from the risk of being clogged with fine silt. Some of the nymphs that move quickly show the "stream-line" form of body that is seen in many aquatic animals, such as fishes. In the young Mayflies it is adapted to reduce resistance when they are swimming, and also to lessen the grip of the current when they are holding on. In many cases there are grappling hooks on the limbs which clutch the surface of stones, and there is a correspondence between the flattening of the body and the rate of the stream's flow. That is to say, when the current is very rapid the only kinds of Mayfly that can live in it are those with a much flattened body. In a kind called Rithrogenia, which lives in torrential streams, attempting the next-to-impossible as animals so often do, the tracheal gills are flattened and extended laterally, so that they rest against the stone, and form a large oval attachment-disc of singularly limpet-like form. As a great naturalist used to say: Wherever we tap Organic Nature, it seems to flow with purpose. In other words, all living creatures are bundles of fitnesses, though the adaptations are more striking in some cases than in others. We could not find a better illustration than the limpet-like grip of this particular Mayfly nymph that lives in the rush of mountain torrents. How different, on the other hand, is the habit of a common American Mayfly, called Hexagenia, that burrows in the bed of the river or lake. The forelegs are flattened into scooping shovels, the jaws form relatively enormous projecting tusks! By using these two body-tools alternately, this young Mayfly tunnels its way along—a sort of sub-aquatic mole!

Many of the aquatic larvæ of insects depend for their food on very minute living creatures that drift or swim in the water. They differ in

Photo: John Armitage.

DRAGON-FLY (*Libellula quadrimaculata*) ON "COTTON GRASS."

This beautiful photograph shows a very common broad-bodied dragon-fly resting on the cotton-sedge (Eriophorum), oftener called cotton-grass, of wet moors. It is predominantly brown with yellow patches. The name quadrimaculata refers to the four spots on the front margins of the wings.

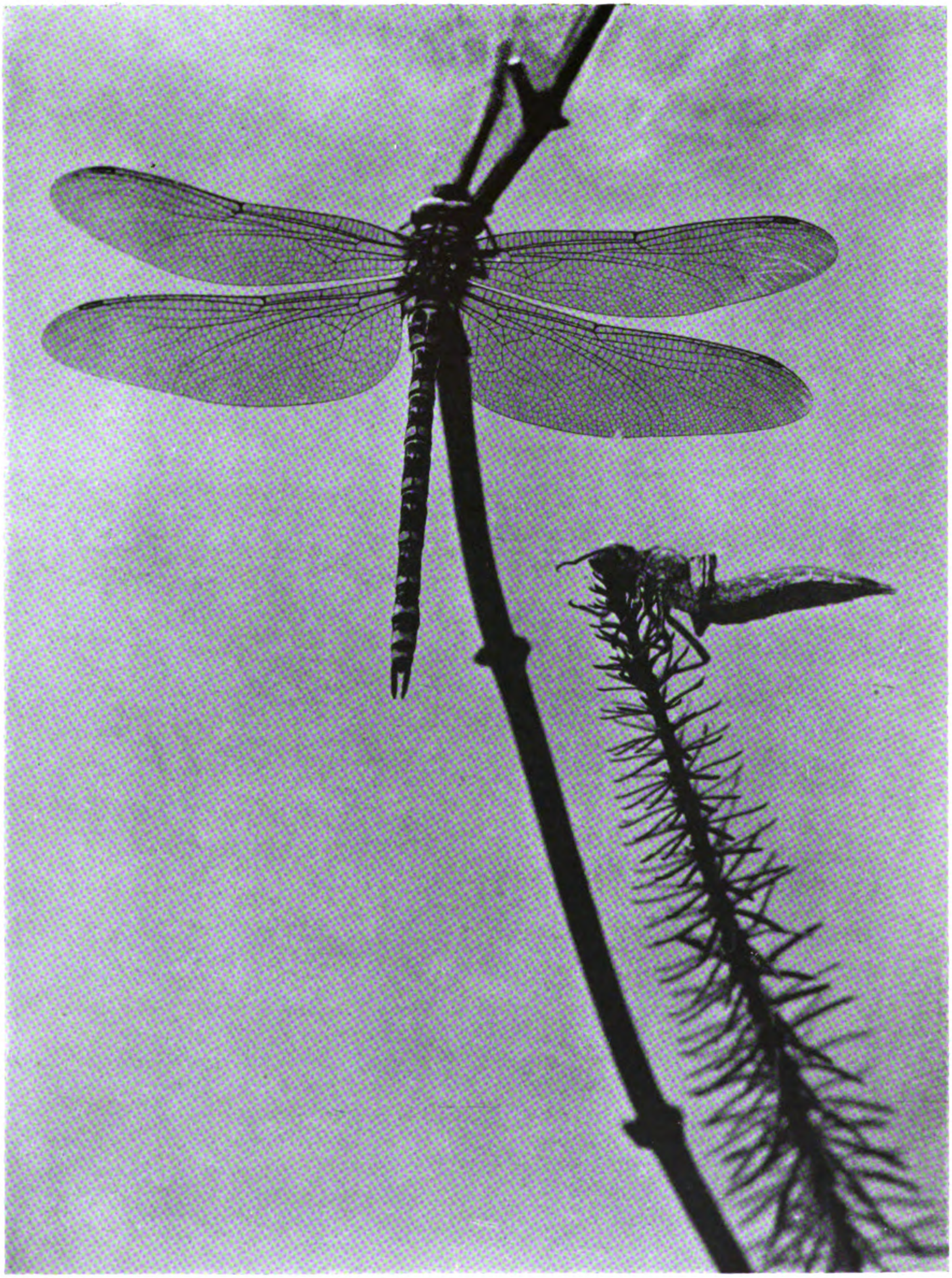


Photo: John J. Ward, F.E.S.

DRAGON-FLY (Æschna) JUST EMERGED FROM THE NYMPH STAGE.

This is a large Dragon-fly, sometimes 2½ inches in length. The photograph shows the big eyes meeting one another on the top of the head The posterior body or abdomen is very long and narrow. On a Mare's Tail to the right is seen the empty cuticle of the nymph, from which the adult has emerged.

interesting ways in their methods of capture. Thus the aquatic larvæ of some flies have rapidly vibrating fans that make a whirlpool around the mouth, sucking in microscopic food. Or again, some of the caddis-worms make delicate and beautiful seine-nets of silk, which strain minute organisms out of the currents passing through. The larval stage of the "Howdy" Mayfly which is almost as quick as a minnow, holds firmly to a stone with its middle and hind-feet, and "extends its fore-feet with their paired fringes of long hair outspread like a basket to receive what booty the current may bring." Many larval Mayflies, however, browse in a more commonplace way on the microscopic vegetation that adheres to the surface of the stones they frequent. Others climb up the stems of water-plants, browsing as they climb. On the whole, they are vegetarians or devourers of the fine organic dust that is floated away from decaying plants and animals.

After the relatively long period of aquatic life, lasting for weeks or months or years, and punctuated by successive moultings (a tax, as we have seen, on growth), the young Mayflies undergo a remarkable change of structure—the metamorphosis. The end of this is that the nymphs float on the surface of the water, wriggle themselves very rapidly out of their split husk, emerge as winged insects and fly away. Sir John Lubbock spoke of the suddenness of the transformation: "From the moment when the skin first cracks not ten seconds are over before the insect has flown away." If we are fortunate enough to catch on our sleeve a Mayfly that has just left its nymph-husk floating on the surface of the water and taken its first flight, we may observe that it seems impatient to get rid of yet another envelope which enswathes its body. The casting of this thin greyish cuticle is the beginning of adult life. In small Mayflies, the resting associated with this final moult (the "subimaginal quiescence" the entomologists speak of) may last for only a few minutes; in larger forms it lasts for a day or two. But whether it takes minutes or days, the outcome is the same—the unveiling of a graceful winged insect with smooth and shining surfaces and beautiful colouration. It rests on our sleeve quivering after its efforts—a large-eyed, fragile creature with its fore-legs stretched out in front, with fan-like fore-wings held up vertically and the hind ones inconspicuous, with two or three long tail-filaments, with minute antennæ and with mouth-parts reduced to remnants. For the time of eating is over; the dance of love is about to begin.

Large numbers of Mayflies often leave the water about the same time and rest on the bushes and herbage, undergoing their final moult. "They often bend the streamside willows with their weight." In the evening, having cast their "ghost," as some of the old naturalists called the last-moulted husk, they rise in countless numbers like a living mist. There are few more impressive sights in the realm of living creatures. In their fine book, "The Life of Inland Waters" (Ithaca, 1916), Professors Needham and Lloyd tell us that "the adult males fly in companies, each species manœuvring according to its habit, and the females come to meet them in the air." The days of hunger are over, it is the hour of love. In his fine monograph on Ephemerids, the Rev. A. E. Eaton describes the behaviour of some of the more conspicuous Mayflies, especially the males. An intermittent action of the wings results in "a dance-like motion almost vertically up and down—a fluttering swift ascent, and then a passive leisurely fall, many times repeated." The cloud of wings rising and falling over a quiet stretch of the river is a very beautiful sight. There is chasing, embracing, and separating; the pairing is usually during flight. The smooth surface of the water is dimpled when some of the dancers touch it, and it is there that the eggs are shed, in a somewhat random way, it seems. As the evening passes, the Ephemerids may pass also; for the continuance of their race is fatal to the individual life. There is one kind at least in which the aerial life is over in an hour, and in many it is over by nightfall. But there are other kinds that may survive for several evenings if they get suitable rest during the day. In any case, there is no getting past the fact that the dance of love ends in death. But the eggs are laid in the stream and sink down there, so that the future of the race of Mayflies is safe.

We must not think of the story of the Mayflies as if it had a peculiar plot of its own, for, as we have said, there is often a sharp contrast between the youthful feeding stage and the full-grown multiplying stage. We see that in the contrast

between caterpillars and butterflies. What is so striking in Mayflies is that the youthful aquatic period of feeding and growing may last for years, whereas the adult aerial period of pairing and reproducing may be condensed into a few hours. There is an extraordinary vividness here in the rapidity with which death comes as the price to be paid for giving origin to new lives. How true was the saying of the poet Goethe: "Nature holds a couple of draughts from the cup of love to be fair payment for the pains of a lifetime."

Before we leave the Mayflies, let us inquire into the part they play in the economy of Nature. In their juvenile life they are "middlemen" between the micro-vegetation on which they mainly depend, and the numerous carnivorous water-animals, like trout, which feed largely on young Mayflies. They are particularly important as a staple food for freshwater fishes because many of them are well represented by nymphs of good size all round the year. Professors Needham and Lloyd, to whom we are much indebted for their fine account of Mayflies, select as a particular case a kind called Callibætis. "It is an active nymph that swims from place to place by means of quick strokes of its tail and gills, and that clambers freely about over shore vegetation. It is an artful dodger; and it is protectively coloured. It feeds on a great variety of vegetable substances living and dead, and hence finds abundant food in every weedy pond. It is eaten by every carnivore in the pond that can catch it; and, doubtless, it has many enemies that exceed it in swiftness and many others that lie in ambush and capture it by stealth. Hence though nearly always present, it rarely appears abundantly in old ponds." But the practically important fact is that this much appreciated Mayfly has great possibilities of multiplication if it had not so many enemies. Its life-cycle occupies only six weeks, and each female may lay 1,000 eggs. In six weeks these will have developed into 1,000 winged insects—say 500 males and 500 females. But each of these females might produce 1,000 eggs, developing into a total of half a million grand-offspring of the original pair. There would be, theoretically, 125,000,000,000 great-great-grand-offspring. Of course, this does not happen because of the multitude of enemies. But the suggestion arises that if we could shelter the young Mayflies in some artificial pond where there was plenty of food, but an absence of enemies, then it might be possible to rear enormous quantities of young Mayflies that could be emptied into waters where useful fishes abound. And if we scatter Mayflies in the water, we shall assuredly find them in many days in the form of trout!

The Freshwater Crayfish.

Most of the backboneless animals that have found a home in freshwater are small—such as water-snails, water-beetles, water-fleas. But the crayfish, whose name is said to be derived from the French *écrevisse* (this looks too neat to be true), is three or four inches in length. It is exactly like a miniature lobster, usually of a dull greenish or brownish colour, often diversified with a little pale yellow below, and sometimes with a little red about the legs. There is a good deal of variability in the colouring. The

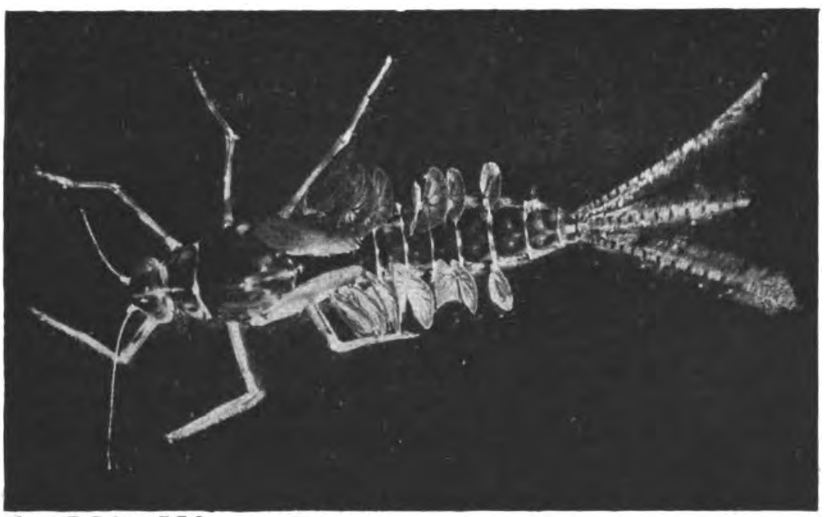


Photo: T. Dobson, F.E.S.

LARVA OF THE MAYFLY (Ephemera).

Most Mayfly larvæ live in running water, but those of *Ephemera vulgata* are found in ponds as well as in slow-flowing streams. The larva has at first no hint of wings; but they grow out later on, and then the stage, still aquatic, is called a nymph. On the sides of the abdomen of the larva there are several pairs of beautiful "tracheal gills." The tail filaments also help in the respiration.

Photo: Hugh Main.

EMPTY CUTICLE OR HUSK OF THE SUB-IMAGO OF A MAYFLY.

Mayflies or Ephemerids are the only insects in which there is a moult after the attainment of the power of flight. Out of the egg comes the larva, which develops into a nymph. This nymph rises to the surface and liberates a winged sub-imago, which becomes the fully formed winged insect—the imago.

The true freshwater crayfish is common in rivers in many parts of the Continent, and is a much-prized delicacy; it occurs in some English rivers, such as the Thames and the Isis; it is not known north of the Tweed, but it occurs in Ireland. It must be regarded as derived from a marine ancestral stock, and the same is true of the freshwater crabs that occur here and there, though not in Great Britain. Similarly, the freshwater slater (Asellus) has been derived, no doubt, from an ancestral stock on the seashore, and the land-slater or wood-louse has gone one better in becoming thoroughly terrestrial.

The crayfish hunts by night and hides by day. It is made uncomfortable

pigment is the same as the lobster's, blue-black, which turns red when boiled. Critics sometimes blame Victor Hugo for calling the lobster "the cardinal of the sea," but he was probably thinking of the Rock Lobster (Palinurus), which is often very ruddy. It is common off the French coast. The same pigment that is bluish in the Common Lobster (Homarus) is red-dish in the prawn, and it is called "zoonerythin," or "animal-red." Chemically considered, it is almost the same as the carotin of carrots. It is well seen in the handsome Norway lobster, which fishermen call the sea-crayfish.

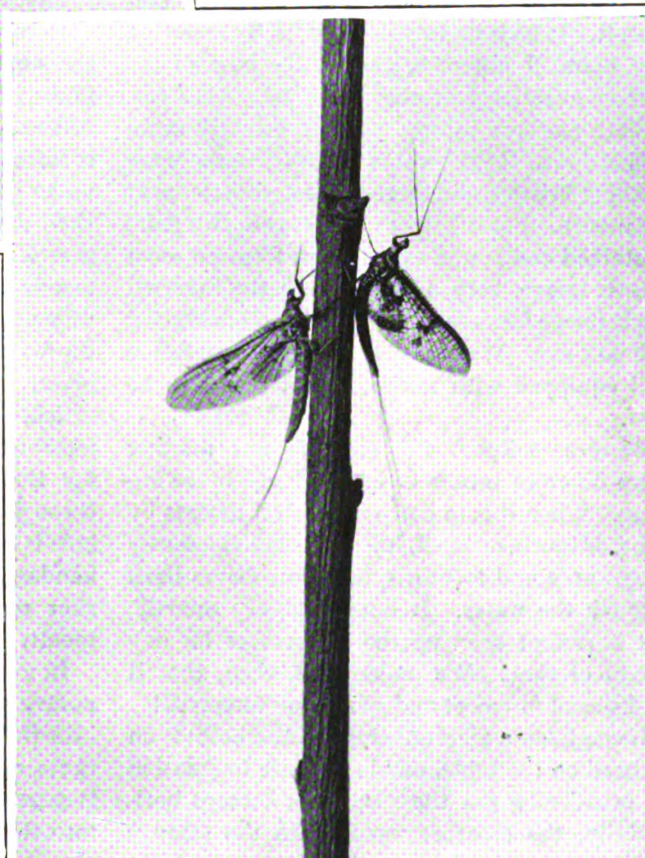


Photo: Hugh Main.

SUB-IMAGO AND IMAGO, THE MAYFLY.

The nymph floats on the surface and liberates a sub-imago in a few seconds. This young winged creature, to the left of the picture, flies away. But it has still to cast a delicate veil before it becomes an imago.

by the glare of the sun, yet it seems compelled to draw to a torch or lantern by night. In a Continental river that we know, the fishermen believe in using a flare, when they work something like a shrimp-net from the boat at night.

The crayfish makes long burrows in the banks of the stream, and it sometimes lurks in the entrance during the day, with its great claws ready for some passer-by. All is grist that comes to its mill, from worms to young water-voles, from the stone-wort (Chara) in the pool to the roots of plants growing on the banks. It is practically omnivorous, and it is always in an animal's favour in the struggle for existence when it is able to thrive on many different items on a long bill of fare.

The crayfish has four pairs of walking-legs, six of which are always on the ground at the same time, when it is walking ; the first three pairs pull the animal forwards, those of the fourth pair push it. It feels its way in the dark by means of two pairs of antennæ, and at the base of the shorter anterior pair there is a balancing ear. If both ears are injured the crayfish will swim upside down. On these shorter antennæ there are smelling-bristles, and there are taste-bristles near the mouth. For daylight use there are two pairs of stalked compound eyes, which form an erect mosaic image, very different from the inverted single image formed on the retina of a backboned animal's eye. We see, then, that the crayfish is well equipped with senses, but it seems to be deaf.

Besides walking, the crayfish has another quite different means of locomotion—by swimming. When it is in danger, which it detects by sight, or touch, or smell, it jerks its tail vigorously downwards and forwards, and thus drives itself through the water. It does this very smartly, but it cannot keep up the tail-strokes for any length of time. We understand, then, that it walks head foremost and swims tail foremost !

If one takes a vigorous crayfish and holds it on its head on the table, making a little foundation by broadening out the nippers or forceps horizontally, the creature passes into the strange state called animal hypnosis. It stands stock-still on its head, and remains motionless for a considerable time. We have seen it stand for five minutes on a class-room table. As one held it, of course without hurting it, one felt the muscles of the tail trying to move, but one did not permit the movement. Commands come from the brain, but the muscles are not allowed to obey ; and the result of this contradiction in terms is fatigue of the nervous system and rigidity of the muscles. Animal hypnosis is next door to animal catalepsy, but it is not quite the same. A similar state may be induced in frog and fowl, in the edible crab and even in a guinea-pig ; but the meaning of it is not yet clear. It was at the basis of the trick the magicians played before Pharaoh long ago, when they turned rods into serpents. That was because they had previously turned serpents into rods ! By-and-by the crayfish comes to itself again, topples on to its feet, and walks quickly away. We do not suppose that the crayfish ever passes into animal hypnosis in natural conditions, but it does something almost as remarkable—it gives off a limb to save its life.

In another connection we have spoken of the surrender and re-growth or regeneration of limbs. When a crab gets one of its legs badly bruised it often throws it off altogether, breaking it across a weak plane near the base. Thereafter, under cover of a bandaging membrane, which is there ready-made, in case of accidents, it grows a new leg in place of the one that could not be mended. The crayfish behaves in a very similar way when it gets into a very tight corner. It throws off a leg or two, almost always at the same place, a prepared "breakage-plane," across which, inside the hollow limb, there stretches a membrane with a little aperture in the middle for the necessary artery and nerve to pass through. When the leg is broken off, the little hole is closed up by a blood-clot ; and inside the bandage a new leg is formed in miniature, to be shot out like a Jack-in-the-box at the next moult.

In autumn the mother crayfish makes a temporary basket by bending her tail forwards, and into this the eggs, like small unripe white currants, are liberated. At the same time some glue is secreted from the underside of the tail, facing into the interior of the temporary basket ; and the eggs are thus firmly fastened to the small paddle-like limbs called swimmerets. There they are fertilised by the male crayfish ; and there, in safety, they undergo their slow development, for they are not hatched until early in the following

Photo: E. R. Gamage.

FLAMINGOES IN THE RIVER (Phœnicopterus).

The Common Flamingo (*Phœnicopterus ruber*), with beautiful plumage, mostly varying from rose-red to carmine, frequents Mediterranean coasts, but has been seen on the Rhine and other rivers. They are gregarious birds, often forming large flocks; they search for small water-animals in the mud, turning their long twisted beak upside down. They sleep on one leg.

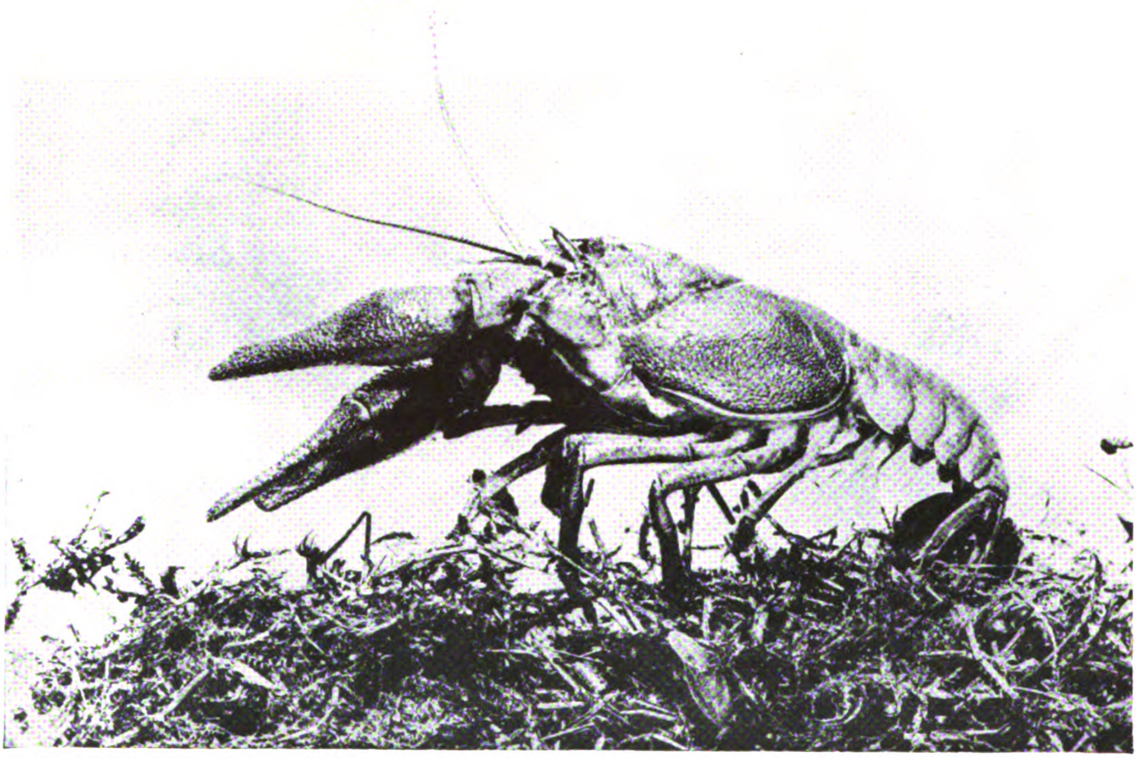


Photo : F. Martin Duncan, F.R.M.S., F.Z.S.

FRESHWATER CRAYFISH (*Astacus* or *Potamobius fluviatilis*).

This well-known crustacean, also called Potamobius, is large for a freshwater animal, being three or four inches in length. It is usually of a dull greenish or brownish colour, often pale yellow below, sometimes with a good deal of red on the limbs. In rare cases, as Huxley noted, the general colour may be red or blue. The name is either from the French écrevisse or the Low Dutch crevik.

summer. When the female is carrying the eggs, she is said to be " in berry."

In the life-history of freshwater animals, as we have seen, there is always a risk of the juvenile stages being swept down to the sea. One way of meeting this risk is to have suckers and grappling structures ; and the young crayfishes have the tip of their great claws turned in, and the ends of the last two " walking legs " hooked. These inturnings and hooks make it easier for the young ones to grip the mother's swimmerets or the empty egg-shells which are still glued on. Another way of meeting the risk of being swept away is to telescope or shorten down the juvenile stages; and this is very marked in crayfishes, for what comes out of the egg may almost be called a miniature of the parent. As the little creature grows, it has to moult, for the protective armour has no life in it and cannot grow. There are eight moults in the first year, five in the second, two in the third—all fatiguing and dangerous. They represent the tax that the crustacean has to pay for its armour. In another place we have discussed the process of moulting, its uses and dangers.

" Merrows from the Quag."

Many ponds and marshland pools are frequented by newts—slow-going, tailed Amphibians, distantly related to frogs and toads, more nearly related to salamanders. There are three different kinds in Britain—the Crested Newt, the Smooth Newt, and the Palmated Newt—and they are first cousins, belonging to the genus Molge or Triton. Their shape suggests lizards, which are reptiles, while newts are true amphibians, with a naked moist skin and without claws or ear-openings. When they are young they breathe by gills, which are never seen in reptiles. Popularly the word " eft " is applied to newt and lizard alike, and the two very different creatures seem to be mixed up a good deal in ancient lore and superstitious prescriptions. Our heading refers to one of John Masefield's poems, where he speaks of

" The water-rat that gnaws the yellow flag,
Toads from the stone and merrows from the
quag."

There is something slightly repellent in the cold clamminess of the newt's skin, but no unprejudiced person can deny the animal's beauty. It has pleasing lines and its swimming movements are graceful. There is a high crest along the back of the breeding male of the Crested Newt and the Smooth Newt, and both show a pleasant yellow or orange colour on the under surface of the body. The courting dress of the male Smooth Newt includes a glittering blue stripe on each side of the tail, interrupted by vertical dark spots. Artistically regarded, newts require no apology.

For most of the year newts are terrestrial, creeping slowly about in moist places in search of small insects, slugs, and worms, or, in the wintry months, lying motionless in a hole, sometimes in little companies. When spring comes they seek out the water, and they may have a long way to go. Like many other animals, they return for breeding purposes to the racial headquarters, for newts belong to an aquatic stock, and the early gill-bearing life must be spent in the water. The only exception is when some very unusual arrangement has been arrived at, as in the Black Salamander of the Alps, where the whole metamorphosis, including the gill-bearing period, is telescoped back into the time before birth.

The newt is of course a cold-blooded animal, with a body temperature approximating to that of its surroundings ; and it is temperamentally cold-blooded as well. Only at the breeding season is there any trace of excitement. The male displays himself before his unemotional mate, he shows off his flushed colours and waving crest, he kisses or butts her head, and fondles her with his very sensitive tail. But, from first to last, it is a cold-blooded business, though a necessary preliminary to the fertilisation of the eggs, which is accomplished in an unusual way. But there is not even croaking.

The eggs are usually laid singly and attached to water plants, such as the pond-weed Polygonum. Each egg is surrounded by a gelatinous envelope, and the mother newt often bends a leaf

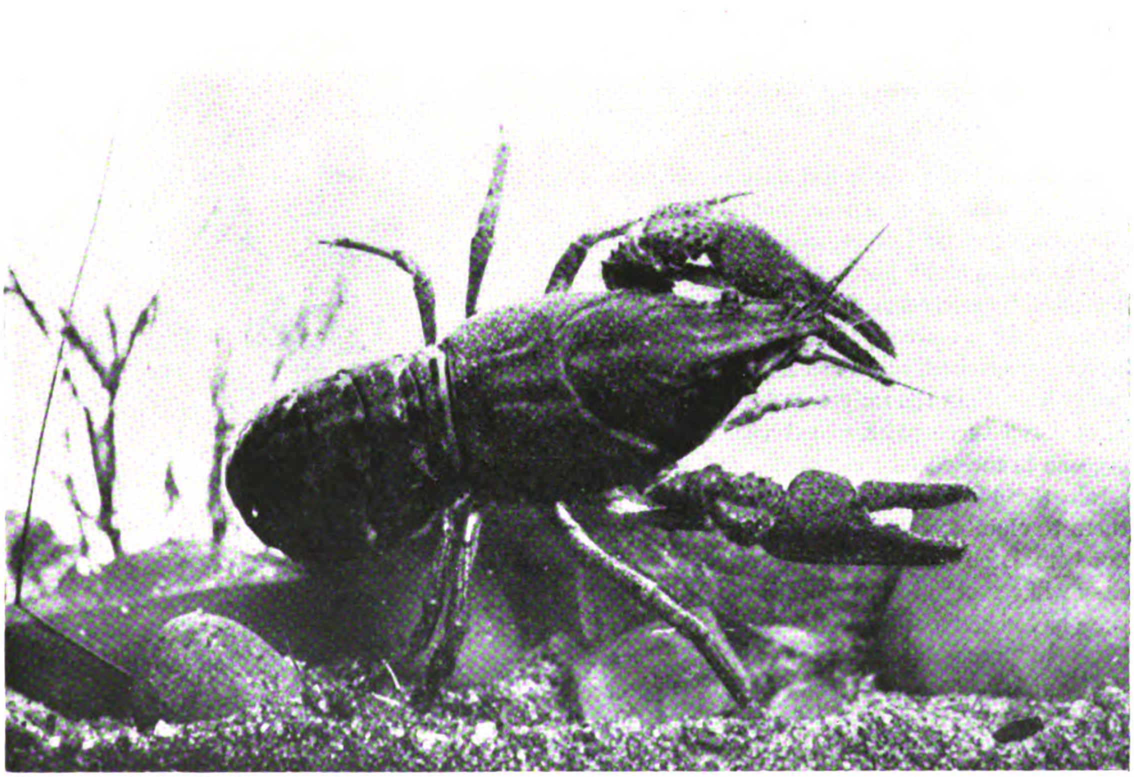


Photo : Stanley C. Johnson, M.A.

FRESHWATER CRAYFISH (*Astacus* or *Potamobius fluviatilis*).

Crayfishes walk along the bottom of the shallow stream by means of four pairs of walking legs, but they can also swim rapidly, tail foremost. They draw the tail forwards and downwards with rapid jerks, and thus propel themselves. In front of the walking legs are the strong fighting and gripping forceps.

Photo: John J. Ward, F.E.S.

1. FEMALE OF THE COMMON NEWT, DEPOSITING HER EGGS.

In this species, *Triton vulgaris* or *tæniatus*, the eggs are fastened singly or in small groups to water-plants, which may be held and folded with the hind-legs.

round so that the egg is not only glued on but well concealed. This is a distinct advantage, for when the eggs are left exposed on stones or the like, as occasionally happens, they are apt to be devoured by sticklebacks and carnivorous water insects. In about a fortnight the yellowish larvæ are hatched, more fish-like and more delicately built than the tadpoles of frogs and toads. They have three pairs of external gills, which become branched as they grow, and they may retain these for a long time if it is difficult for them to clamber out of the pool. If they have not completed their metamorphosis by autumn they will remain in the water all the winter, and they have been seen moving near the bottom of the pool under a blanket of ice! But if the development goes on apace the young are ready to leave the water in autumn. They are sometimes found hidden in clumps of water-weed on the bank, but they afterwards seek out drier spots. The adults usually leave the water much earlier, returning to dry land soon after the end of the breeding season.

There must be a much lower juvenile mortality among newts than among frogs, for the eggs are not nearly so numerous, while the risks are in a general way much the same. How is it that newts have been able to survive with a much smaller family? Part of the answer must be found in the fixing and frequent concealment of the eggs. There seems to be some variability of behaviour in this respect, but the mother crested newt shows a glimpse of care in selecting appropriate water-plants, like the Canadian Pondweed, Anacharis, on which the eggs are very safe. It should be noted that the newly hatched larvæ have two pairs of thread-like outgrowths on each side of the upper jaw, by which they are able to anchor themselves to water-plants. As an

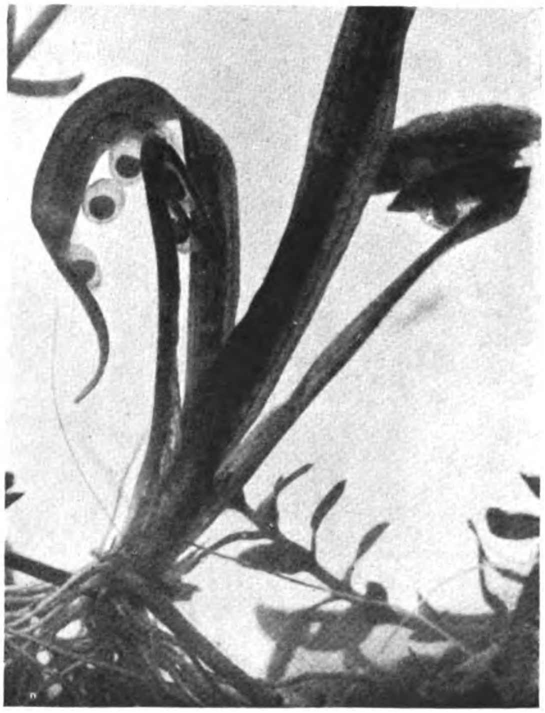


Photo: John J. Ward, F.E.S.

2. THE EGGS ON THE SUBMERGED LEAF.

Each egg is surrounded by a little jelly or white of egg, which is adhesive. Fertilisation is internal, for the excited female takes in packets of sperms (spermatophores) which the male liberates in the water.

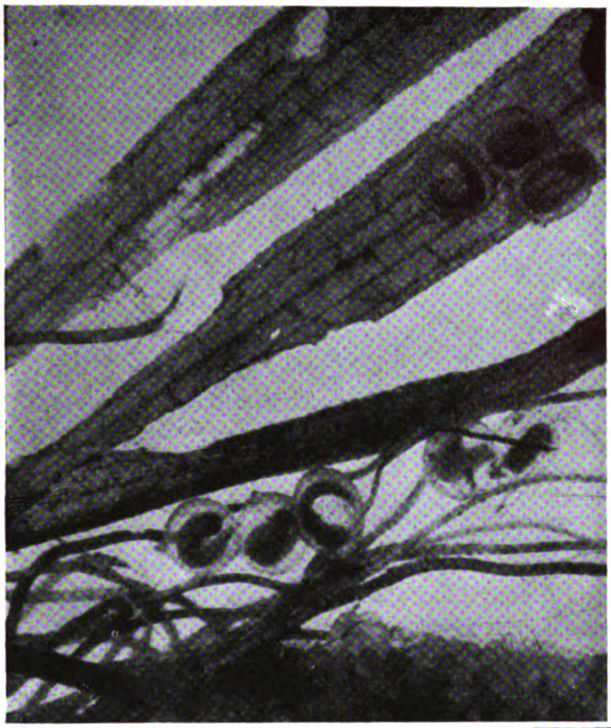


Photo: John J. Ward, F.E.S.

3. SMOOTH NEWT LARVÆ DEVELOPING.

The larvæ, here seen in the jelly, break the egg-membrane in about a fortnight, but this varies with the temperature in the spring.

extreme case of the successful reduction of the size of the family we may refer again to the Black Salamander, which lives terrestrially high up the Alps, preferably near the spray of waterfalls. As we have mentioned, the young of this species develop inside the mother, and there are only two of them! Parental care makes a small family consistent with survival, and the reduction of the family makes parental care easier. This is one of Nature's virtuous circles.

Newts swim after the manner of fishes; that is to say, the muscular undulations of the posterior body and the flattened tail displace masses of water, first to one side and then to the other. The limbs are too slender to be of much use in swimming, but those of our smallest newt, the Palmate newt, are fully webbed. When newts are crawling about on land their limbs seem hardly strong enough for their work. The newt's skin is scaleless and glandular, producing a secretion which seems to make the animal unpalatable. Breathing may take place through the skin, which is the exclusive method in frogs all through their winter lethargy; and here we may notice the occasional disappearance of the lungs in some relatives of the newts, such as certain salamanders. Another characteristic of the skin is the abundance of sensory cells; they tend to be especially localised in a row along each side of the body, thus recalling the sensitive lateral line of bony fishes. This is one of the straws which shows how the evolutionary wind has blown; it discloses to us the fish lingering in the amphibian. The outermost layer of the skin dies away periodically, and the newt moults. In a neat way it uses its fingers to help in the disrobing; the slough is peeled off from the head backwards. No doubt the dead husk sometimes comes off in shreds, but it may form an intact slough, which is occasionally seen, hanging like a ghost of the newt,

Photo: John J. Ward, F.E.S.

4. THE LARVA OF THE SMOOTH NEWT.

The larva, liberated into the water, has three pairs of branched external gills on the sides of the neck. It is marked by yellow dots on the body and on the tail, which ends on a slender thread. (*The story is continued overleaf.*)

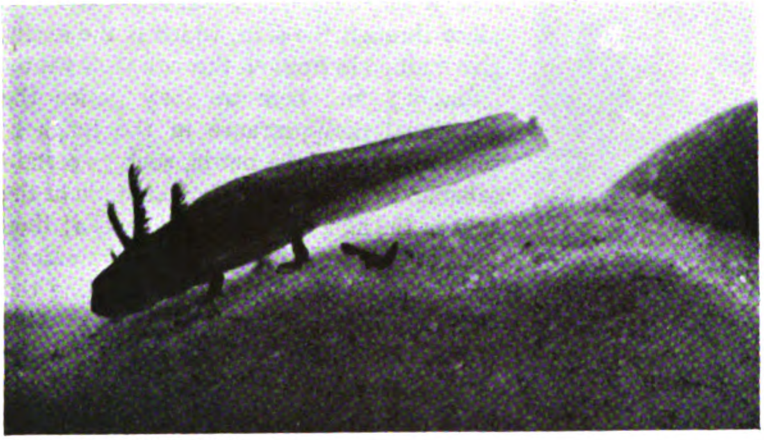


Photo : John J. Ward, F.E.S.

5. THE LARVA CONTINUES ITS DEVELOPMENT.

The young Newt remains a larva, that is with certain juvenile characters like gills, till the end of its first summer. Then it has become a lung-breather and must get on to dry land.

among the water-weed in the aquarium. We say "occasionally," for when the newt has got rid of its slough, turning it inside out, it normally ends by swallowing what it used to wear. The newt has a frugal mind.

There are many other interesting facts about newts, such as their successful re-growing of limbs that have been bitten off ; or the way in which they occasionally produce eggs while still gill-breathing larvæ, a peculiarity probably due to something wrong with their ductless or hormone-making "endocrine" glands. But perhaps the greatest interest of newts is that they represent the pigmy descendants of large and vigorous forms that helped in colonising the dry land in Devonian and Carboniferous Ages.

That the interest of an animal is not in proportion to its size, is well illustrated by the sticklebacks. They are the smallest of the British freshwater fishes, but they are among the most interesting. They have a strong pugnacity linked to an equally strong paternal care ; they have quaint ways and much variability. There are at least three distinct kinds on the British list: the three-spined, the ten-spined, and the fifteen-spined sticklebacks ; and these are usually referred to three *genera*, which means a much bigger distinctiveness than if they were three different *species* of one genus.

Stickle-backs.

The three-spined stickleback (*Gastrosteus aculeatus*) is widely distributed in the Northern Hemisphere, both in rivers and in the sea, from Kamschatka to Spain, from Alaska to California. It is a good example of a big soul in a little body, for it fears no foe although it is never over four inches long. In some localities, especially in the north, it is chiefly marine, and may form a choky part of the palatable ichthyological collection called "whitebait"; in other places, like the Mediterranean Basin, it is practically confined to freshwater. Its external characters often differ in detail in different habitats. It is a plastic creature. A sudden transference of freshwater sticklebacks into the sea is apt to be fatal; but individuals that live in estuaries, where the water is betwixt and between, are quite comfortable whether they journey riverwards or seawards. In both habitats they sometimes occur in shoals, which feed greedily on insect-larvæ, small crustaceans and worms. They cannot be acquitted from the charge of devouring the eggs and fry of other fishes. Their appetite is large, and they hang on like a bull-dog to their victim. Their pertinacity of grip leads to ready capture at the hands of youthful anglers who need little skill to land a "tittle-bat."

When the breeding season draws near, usually about the end of spring or the beginning of summer, the sticklebacks put on their wedding robes. The dark green of the back spreads in bars down the sides ; the under surface becomes brilliant red in the males. The same part is usually silver or gold in the females, who seem to be greatly in the majority. In an overflow pool of the river, or in some quiet shallow reach, or in a shore-pool near high-water mark, the male builds his nest. In this species it is constructed of pieces of plants, which are tied neatly together by means of sticky threads which exude from the kidneys. The result is like a barrel lying sideways, about an inch in diameter, with an opening at one of the ends, or like a dome with the opening at the top.

It is attached to the bottom of the pool. The making of the nest occupies several days and the male is very intent on his work and very jealous of intrusion. After it is finished he goes in search of a mate, whom he courts with evident piscine enjoyment. He leads her to the nest, partly by cajolery, and partly, if need be, by coercion. She enters, lays a few yellowish eggs and after four or five minutes breaks her way out at the end opposite that by which she entered. She is off without a good-bye, and the subsequent proceedings interest her no more. The male then enters the nest and fertilises the eggs. Next day the little polygamist is off after another mate, and the process is repeated, until there are a good many eggs in the nest. The number must be such as to counterbalance the chances of death—for this is the law of life. The male stickleback is no stickler as to the number of his wives.

Photo: W. S. Berridge, F.Z.S.

THE FEMALE MARBLED NEWT (*Triton marmoratus*).

This species is grass-green above, brown below, with numerous dark patches and dots. It is confined to France, Spain and Portugal. The male has a crest, but it is not serrated as in the Crested Newt. The female has an orange line along the back.

Not only does the male guard the nest from the intrusion or indifferent approach of another animal, he fights with his next-door neighbours furiously. These combats afford opportunity for a brilliant display of the masculine wedding robes, for under the excitement the red pigment-cells seem to become larger, so that the total colour is more intense. The fighting is often far from playful, for one "Jack Sharp" to use another of the many names, may rip up his rival, using the hinged dorsal spines as weapons. The male, victorious in love and on the field, then becomes more domesticated. He takes up a maternal rôle, mounting guard over the nest. With his mouth he mends breakages and with his fins he fans so that the contents of the nest are well aërated. With his mouth, by-and-by, he catches hold of the youngsters if they try to

Photo: E. Step, F.L.S.

FEMALE PYRENEAN NEWT (*Triton asper*).

This sluggish Newt is confined to the Pyrenees, and is said to prefer lakes that are fed with water from glaciers. The male forms with his tail a noose round the female, and the sperms pass directly from him to her.

hurry away too soon from the guarded safety of the nest, or, more strictly, of its foundations, for it is in great part dismantled after the larvæ are hatched. In any case, if one may use the expression of a fish, the male stickleback's hands are kept very full until the family starts on the adventurous voyage of life. There are perils enough ahead, but the launching has been a success.

The Ten-Spined Stickleback (*Pygosteus pungitius*), otherwise known as the Tinker, has seven to twelve low spines and does not exceed three inches in length. It does not extend so far south as the Three-Spined species, and its northern limits in Scotland seem to be the Forth and Loch Lomond. It is more consistently a freshwater fish; the male is dark brown at the breeding season; the nest is not fastened to the bottom, but to water-weeds.

The Fifteen-Spined Stickleback (*Spinachia spinachia*) is large compared with the others, being five to seven inches in length. It is exclusively marine and builds a nest in shore-pools. The materials are seaweeds and zoophytes, bound together by the delicate threads exuded from the kidneys. This is very like an abnormal condition becoming normalised, for if the kidneys of any other animal were to begin producing this mucous secretion we should certainly call it a disease. It is confined to the breeding season and to the male. We cannot help wondering if the males do really recover; we should like to know more about them. According to some authorities, sticklebacks spawn only once in their lifetime, and do not live more than two or three years altogether. It is worth considering whether the female's apparent indifference may not mean that she is fatally spent by the spawning, while the male, with less parental sacrifice and perhaps a tougher constitution, lives on and takes charge of the eggs and the young. Inquiry should be made, however, to discover whether he does not succumb to his labours.

There are many other interesting features of stickleback life, and it is certain that they would repay further study. They are among the few fishes that can swim by means of pectoral fins, which are usually balancing organs. The marine stickleback may be seen moving head-foremost or tail-foremost, rowing gently with its pectoral fins; but when it is in a hurry it exhibits the usual wavy movements of the posterior body—the orthodox method of swimming among fishes. Then there are the rapid respiratory movements of the mouth and gill-cover, sometimes 150 per minute, as if the little creatures were panting. Of interest also are the experiments showing that sticklebacks kept on white tiles become bleached, and that if the exposure has been prolonged they have some difficulty in recovering themselves when restored to a normal environment. There is a great deal to be found out in regard to sticklebacks.

Photo: W. S. Berridge, F.Z.S.

THE IBERIAN NEWT (*Triton waltli*).

This Spanish newt may attain a length of ten inches. It is olive-brown above, yellowish with dark markings below. A curious peculiarity, which occurs also in another newt from the Loo-Choo Islands, is the great elongation of the ribs which sometimes pierce the skin and project.

Concerning Leeches.

While there is a great variety in the habitats of leeches, the majority live in ponds and rivers. So in spite of land-leeches, tree-leeches, and sea-leeches, we give the class its place here among the freshwater animals.

The medicinal leech (*Hirudo medicinalis*) shares its name with the physician who used to

Photo: M. H. Crawford.

NEWTS IN THE WATER.

These two Newts of quite different kinds show the general sameness of form. An obvious adaptation to aquatic life is the lateral flattening of the tail, suited for displacing water sideways in swimming. The weakness of the legs shows that the adjustment to terrestrial life, to which newts usually attain, is still only beginning. All have gills as larvæ and lungs as adults.

carry it about so faithfully and rely on it so much. Where we would say, "Send for the doctor," our forefathers said, "Send for the leech." The animal owes its virtue to the neatness of the three-rayed cut which it makes in the patient's skin. There are three semi-circular saws in the mouth, each bearing about ninety teeth, and the wound remains open as long as the leech continues sucking. In natural conditions the leech feeds on the blood of fish and frog, with which it fills ten capacious pockets on each side of its food-canal. It is said that a good meal of this highly nutritive fluid can keep a leech going for many months, and it is a very interesting detail that, as the blood is sucked in, it is subjected to the action of a secretion which prevents coagulation. The common horse-leech (Hæmopis) of ponds has not got such finely developed jaws and teeth as the medicinal leech; it has only two pouches; it cannot contract itself into a plump olive-shaped form; it does not suck blood, but swallows worms and aquatic larvæ. It often makes a burrow in marshy ground when the autumn comes, and, doubling itself ventrally, passes into a lethargic state. As many as sixteen have been found together under one stone in a marsh.

The brook-leeches usually lay their eggs separately on stones or water-plants, and, brooding over them, get them fixed on the underside of the body, where they hatch. The young are exquisitely sensitive to the touch of the body of their kin, and return to shelter (not necessarily their proper parent's) even after they have begun to make excursions on their own account. Like all other members of the class, these brook-leeches (Glossiphonia and the like) are hermaphrodites, the two sexes being combined in one, as is also the case with earthworms and snails and many other humble animals. They are cross-fertilising all the same, not like liver-flukes and tapeworms which fertilise their own eggs.

Photo: *John J. Ward, F.E.S.*

1. THE DUEL OF THE MALE STICKLEBACKS (*Gastrosteus aculeatus*).

The owner of the nest (to the left) kept a sharp eye on his rival, who might at any moment make an assault, using the three hinged spines as weapons. The female is seen lowest down.

over them for many weeks—keeping them clear of mud and the like. This prolonged parental care at a low level in the animal kingdom is very interesting; it is an other-regarding activity; it is of no apparent use to the individual. Easy enough is it to say that this parental-care habit has become hereditarily engrained or instinctive; but one wishes to know how habits involving the expenditure of energy along lines far from being those of least resistance or self-preservation have been established, and have kept agoing with such imperative force. What can one say but what Darwin said, that in the struggle for existence, which includes all answers back to surrounding difficulties and limitations, success in leaving progeny pays as well as success in filling the mouth or keeping the skin whole? What one must not think, however, is that animals deliberately run their individual lives on "sound business principles."

On a different line altogether are the fish-leeches, which have no jaws nor red blood, but a protrusible proboscis. Very well-known is the skate-sucker, Pontobdella, covered with green warts. It is sometimes seen holding itself horizontally taut against a rock that goes down into deep water, and suddenly launching itself on to a passing fish. In an aquarium these skate-suckers usually remain sluggishly in the mud, but when a piece of skate is dropped in they are instantaneously on the qui vive; they have it—or one of them has it—before it reaches the bottom. Exquisite sensitiveness to different kinds of external stimuli, luminous, odorous, chemical, and so on, is very characteristic of leeches when they are hungry; but gorged individuals are as markedly unresponsive. It is the same skate-leech that lays its velvety eggs in the shelter of an empty bivalve shell, and mounts guard

Photo: *John J. Ward, F.E.S.*

2. MALE STICKLEBACK DEFENDING THE NEST.

The stickleback guarding the nest charged the intruder and hurled him off. His tail is seen disappearing on the left. The shadowy form below is the excited female fish.

Photo: John J. Ward, F.E.S.

3. THE MALE STICKLEBACK RETURNS TO GUARD.

After routing his rival, who turned tail, the victorious stickleback returned to the nest; and the interested female came to rest in his vicinity.

of the British Museum, has suggested that Gideon's sifting of his soldiers by distinguishing those who knelt to drink the water directly from those who used the cupped hand to lift the water to the mouth may have had reference to the danger of becoming infected with leeches. The danger has been circumstantially illustrated in the case of soldiers in the East. The leech in question (*Limnatis nilotica*) is very slender when it lives freely; but in the back of the nasal chamber it gorges itself with blood and becomes as big as a medicinal leech—a very troublesome intruder and difficult to dislodge. The moral is not to drink in the dark.

From an allotment in Finsbury Park a friend in London sent us the other day a large land-leech. It was a giant compared with the inch-long land-leeches of India and some other warm countries —for it attained to a length of five

Their "principles" are enregistered in their constitution.

Travellers tell us of losing their way in a tropical jungle and hearing in the silence a steady drip-drip all around—a shower of land-leeches. They are only an inch or so in length, and no thicker than a coarse knitting-needle; but there are hundreds of them—all hungry. When the traveller is delayed they overtake him, with a graceful, but gruesome, looping movement, as if they made leap-frog of themselves. We read in the "Cambridge Natural History" that "a whole battalion of English soldiers decamped on one occasion from a wood which was overflowing with land-leeches." There seems to be something poisonous in their bite. In Egypt long ago Napoleon's soldiers were troubled by slender water-leeches which fastened at the back of the mouth, and Sir Sidney F. Harmer,

Photo: John J. Ward, F.E.S.

4. THE FEMALE ENTERS THE NEST.

The female, sympathetically interested in the male, who now seems more brilliantly coloured than ever, is induced to enter the nest, in which she lays a few eggs, and then goes her way.

inches. Not that a conscientious person finds it very easy to record the dimensions of a live leech. They vary so much with the changeful taste and fancy of the specimen—now long and thin, now short and plump. This ruddy-green leech from London was probably an alien, apparently of the tribe of Trocheta; and from the bath which he was offered after his long journey he promptly fled, and hid himself in the soil. There he soon disposed of a small earthworm, swallowing it whole, which is another of the ways of Trocheta. After three days, in spite of unremitting hospitality in the form of baths, varied soil, diverse temperatures, and plenty of earthworms, the interesting alien died. It seemed to be closely allied to, if not identical with, Dutrochet's Leech (*Trocheta subviridis*), which has been recorded not a few times from London and the suburbs, and farther afield. It is known in France, Italy, and Algiers. It is said to enjoy foul streams; it explores gardens and parks; its jawplates are rudimentary; it swallows small earthworms whole, and they form its staple food.

Around leeches some quaint lore has gathered like moss on a stone. Thus, Burton speaks of horse-leeches being much used to drive away melancholy, and the old books give recipes like this: "Take horse-leeches and burn them to powder, and mix with eyesel; then use to rub the place therewith where you would have the hair grow no more, and there will no hair grow on that place." Leeches were once used almost as widely as blood-letting, but their day is almost over; and the physicians of to-day have almost forgotten the creatures which, if they did not actually give their name to the profession (Dryden, for instance, wrote "wise Leeches will not vain receipts obtrude"), came, by some etymological twist or other, to share it. But if leech-lore and leech-craft have passed away, natural history remains, and that of leeches is far from being a finished book. The number of interesting "ken speckle" forms is large. We recall Branchellion on the Torpedo with eleven leaf-like gills on each side of its body; its relative Ozobranchus on a river-turtle of the Yang-tse-Kiang; the Lophobdella of the Crocodile's lips which the "Ziczac" Courser Bird, the Trochilos of Herodotus, cleans off; the Chilian burrowing leech (Macrobdella), which may be over a foot long; the still larger red leech (two feet long!) which Pennant described as always falling off the Basking Shark when that huge fish is brought to the surface; the deep-water Ancyrobdella, from Lake Biwa, in Japan, which has three grappling hooks directed obliquely backwards at the end of a long proboscis; and rare marine leeches from the angler-fish and the dragonet which seem to be in process of sinking down to the level of stationary parasites.

And not only are there many imperfectly known forms, there are many imperfectly understood facts. We smile at the observation of the old physician Mercurialis, who stated that the medicinal leech made so small a hole in man's skin that only the thinner part of the blood passed out; but we are far from being done with

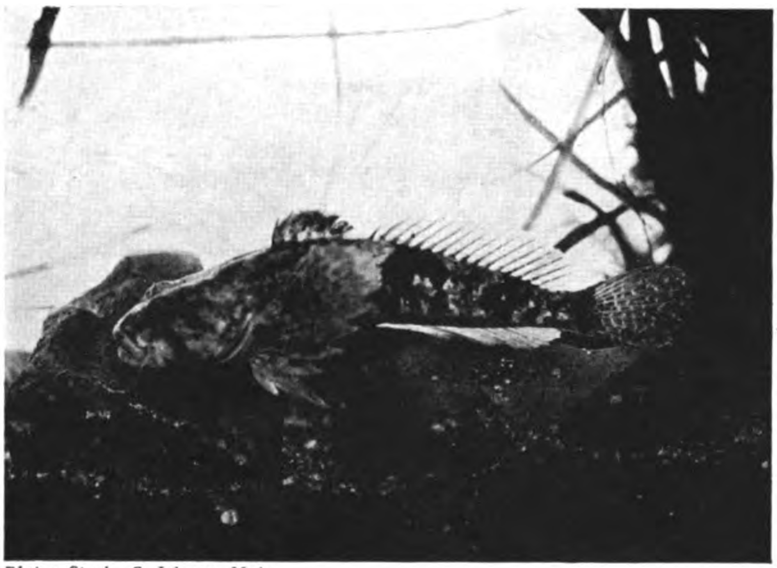


Photo: Stanley C. Johnson, M.A.

THE MILLER'S THUMB, OR BULLHEAD (*Cottus gobio*).

This common freshwater fish has a broad depressed head, rounded in front; and an almost cylindrical body, tapering backwards. The skin is without scales; there are strong spines on the gill-covers; the pectoral fins are very large. A common length of body is three to four inches. The favourite haunts are clear brooks and shallow lakes. The food consists mostly of worms, insect larvæ, small crustaceans, and the like.

Specially drawn for this work by E. Mansell.

NESTING OF THE STICKLEBACK.

The Three-Spined Stickleback, *Gastrosteus aculeatus*, also known as Prickleback or Tittlebat, is widespread off the coasts and in the rivers of the Northern Hemisphere. It never exceeds four inches in length, but is of large courage. It feeds on aquatic insects, crustaceans, worms, and the like. The male makes a nest about an inch in diameter, of pieces of roots and stems of freshwater plants, bound together with glutinous threads and fastened to the bottom by sand and pebbles. The female lays a few eggs in the nest and breaks out on the side opposite to the entrance. Another female is then brought in to add to the possible family. The nuptial colours of the male are exceedingly beautiful.

the study of the leech's secretion called "hirudin" which keeps the blood from clotting, and is used for this purpose in some physiological experiments. We smile at the old recommendation to one who had swallowed a leech that he should get into a hot bath, yet keep cold water in his mouth, since the leech would be attracted thereto; but we are far from being done with the sensitiveness that many leeches show to distant stimuli—a shadow over the aquarium, disturbances of the water (as Wordsworth described), and the approach of suitable food. There is still much to be learned concerning leeches.

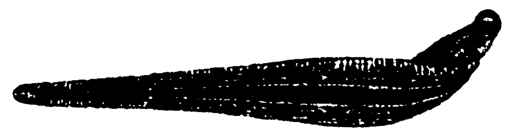


Photo: E. J. Manly.

THE MEDICINAL LEECH (*Hirudo medicinalis*).

This Leech, once so much used in medical practice, is often three or four inches long, but may reach six. It is cylindrical or strap-like according to its state of contraction. The anterior end bears the adhesive and blood-sucking mouth; the posterior end has a large circular sucker for adhesion only. The leech moves by looping the body over a surface, fixing and loosening the two ends alternately, but it can also swim beautifully in the water.

Every observer of pond life is familiar, more or less, with the Hydra, or freshwater polyp, which is found everywhere in clean pools, hanging on to aquatic plants.

The Hydra.

It is a small tubular animal, a quarter to a half of an inch in length, and as narrow as a needle. There are green, brown, and greyish species. It has a crown of six to ten hollow tentacles around the mouth, and it usually hangs head downwards from the water-weed. In many cases it is attached to the under surface of the tiny green shoots of the duckweed (Lemna), which is the second smallest flowering plant in Britain. Indeed, very few people have seen its flowers. With its tentacles the Hydra stings and lassoes small animals, such as water-fleas, and these tentacles may be elongated till they are three or four times longer than the tubular body. But when the water is disturbed the tentacles contract to minute knobs, and the Hydra cowers against the water-plant till it is very inconspicuous indeed. The green species is of course more difficult to detect than the brown one or the grey one. When the duckweed is put into a glass vessel, preferably with flat sides, the Hydras usually take up their position so as to get most light. It is quite easy to prove that the polyps can shift from one side of the vessel to another, but if things are going well they remain for a long time attached to the same spot. One can see them swaying gently in the

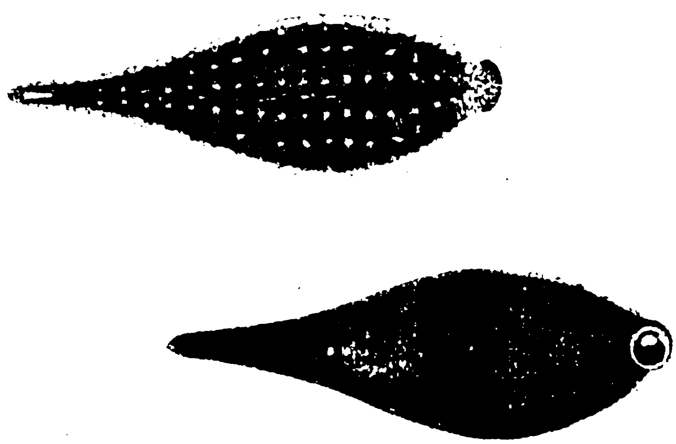


Photo: E. J. Manly.

THE BROOK LEECH (*Glossiphonia complanata*).

There are many species of Brook Leech, also called Clepsine. The body is much flattened; the mouth sucker is not sharply marked off; the posterior sucker is small and almost hidden from above. The movements are sluggish; there is no swimming; the animal rolls itself up when disturbed. They suck molluscs and worms in the water. They are often to be found by turning flat stones in the stream upside down.

water, and watch the elongation and retraction of the thread-like tentacles. The Hydra is a very simple animal, but it is full of interest.

The Hydra was discovered during one of the intensely active periods in the history of zoology, when the introduction of the microscope opened up a new world. Not only was there a disclosure of an unexpected and fascinating intricacy in the structure of such animals as insects, but a large number of new creatures came to be known. One of these was Hydra, and its date was 1702, when that extraordinary observer Leeuwenhoek described it to the Royal Society of London. He was also the first to speak of Bacteria and to make a microscopic study of yeast! Of the Hydra he says quaintly that its tentacles, seen under the microscope, seemed to be several fathoms long; but more important was his statement that the polyp formed buds which are set adrift. He also saw a little parasitic Infusorian swimming about on the surface of the Hydra, just as we see it to-day. The Hydra must have got accustomed to it, for it does not excite the stinging lassoes.

But while Leeuwenhoek was the first naturalist to see the Hydra, its real discoverer was Abraham Trembley (1700–1784), and before us as we write we have his charming book, with beautiful type and illustrations—" Mémoires pour servir à l'histoire d'un genre de polypes d'eau douce."

Photo: John J. Ward, F.E.S.

UNDER-SIDE OF FLOATING LEAVES OF THE PONDWEED (*Potamogeton natans*) BEARING MOTH-LARVÆ, AND TO THE LEFT A LEECH.

The larvæ of the Brown China Mark Moth (*Hydrocampa nymphæata*) are hatched on the leaves of water-plants; they bore into the tissue for a day or two; they then emerge and make a habitation by fastening a piece cut from one leaf to the under-side of another leaf; they are still breathing by their skin and so they remain for the winter. In spring they make a portable house of two pieces of leaf, and this, strange to say, is filled with air; the covering of the larva becomes velvety, entangling air-bubbles, and the air-tubes or tracheæ open.

Trembley was a Genevese, who in 1740 was acting as tutor to the two boys of the Hon. William Bentinck, English Resident at The Hague. In the ponds round Bentinck's country house at Sorgvliet, a mile from The Hague, Trembley used to fish for water insects, and in so doing he found Hydra. He thought at first that it must be a kind of water-plant, with a mobile flower. He knew about the Sensitive Plant, and thought his small captives might be somewhat similar. But when he saw the Hydra move from place to place in his glass vessel he was inclined to conclude that it was an animal. Yet when he cut the Hydra into two parts, and had the pleasure of seeing the posterior half grow a new set of tentacles, he swung back to the view that it must be a plant. At another time he saw the Hydra devouring small water-fleas, and that made him think it was an animal. Yet again he saw one budding and that made him return to the idea that it was a plant. Moreover, some of his puzzles were green and others brown. Another day he saw the Hydra liberate an egg-cell or ovum! Little wonder that Trembley oscillated between regarding Hydra as an animal and

regarding it as a plant. Or could it be some strange "betwixt and between" living creature? In his hesitation Trembley sent some specimens to Réaumur, almost equally famous as physicist and naturalist, who at once declared them to be animals, and proposed the name polyps, originally applied to cuttlefishes. It was Linnæus who afterwards suggested the name Hydra, which recalls the mythical monster with which Hercules contended. When Hercules slashed off a head another one sprouted out, and that is what the little freshwater polyp does. If one is cut up into several pieces, each piece may in favourable conditions grow into a complete Hydra. But the piece must not be too small—there is a *quantitative* limit to "regeneration"; and it must contain a sample of all the different kinds of cells in the body—there is a *qualitative* limit as well.

Photo: E. J. Manly.

THE HORSE LEECH (*Hæmopis sanguisuga*).

The Horse Leech is related to the Medicinal Leech not very distantly; but its jaw-plates have blunt teeth of no use for blood-letting. There are two rows of them with about twenty in each row, whereas the medicinal leech has over ninety sharp teeth in a single row. The Horse Leech is common in streams and ponds. It does not suck its booty, which consists of freshwater worms, insect-larvæ, and the like; it swallows them.

Nowadays we do not hesitate as Trembley did in regard to the animal nature of Hydra, for the essential differences between plants and animals are now understood more clearly. Hydra feeds like an animal; it has animal cells; it develops like an animal; and so on. It belongs to the great series of Stinging Animals or Cœlentera, including zoophytes and swimming-bells, sea-anemones, and jellyfishes; but, like a few others, it has wandered from the old home in the sea and become a tenant of freshwaters. Trembley would probably have been rather staggered if he had been told that his green polyps were dual organisms, for it is generally believed nowadays that the minute greenish corpuscles in the inner layer cells of the green Hydra are partner Algæ, which conduce to the animal's well-being by liberating oxygen and building up carbohydrates. If a green Hydra liberates an egg while kept in the dark, that egg develops into a white Hydra, which is supposed to mean that the partner Algæ do not migrate into the egg when there is no light.

Trembley did not know of the Hydra's numerous stinging cells which penetrate into

Photo: E. J. Manly.

THE SKATE SUCKER (*Pontobdella muricata*).

The Skate Sucker is a strong greenish marine leech with numerous warts all over its skin. It has a strong adhesive sucker at each end, but, as in all leeches, it is only the anterior sucker that sucks in fluids such as blood. Pontobdella often occurs adhering to skates. It lays velvety eggs in the empty shells of molluscs and mounts guard over them for a hundred days or more.

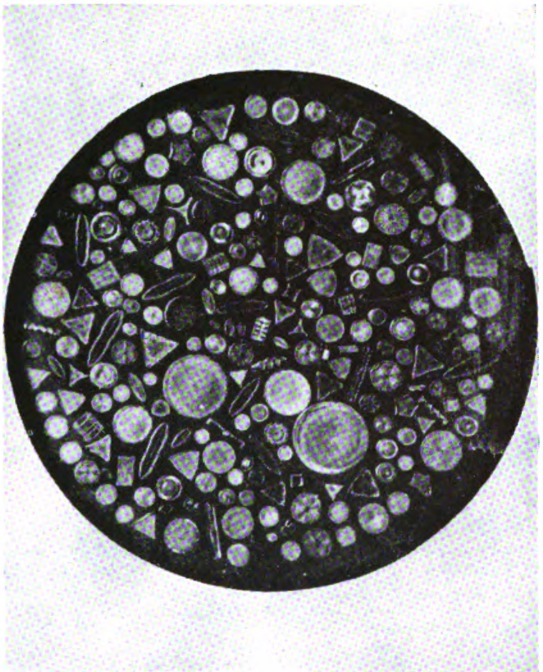


Photo: W. H. S. Cheavin, F.E.S.

SHELLS OF VARIOUS DIATOMS, BRITISH AND FOREIGN.

Diatoms are one-celled plants very common in the sea and in freshwater. They also occur in damp places. The cell-wall consists of two siliceous (flinty) capsules.

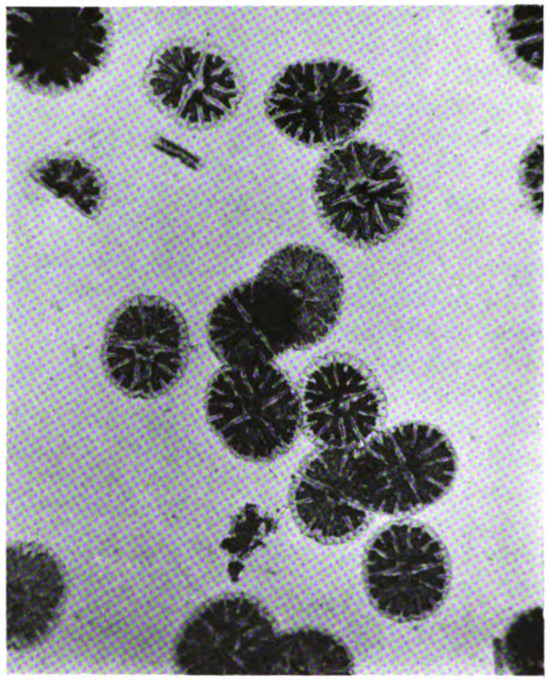


Photo: John J. Ward, F.E.S.

FRESHWATER DESMIDS (*Micrasterias denticulata*).

One-celled plants of great beauty, restricted to freshwater, with a cell divided into symmetrical halves separated by a deep constriction. Many can move about.

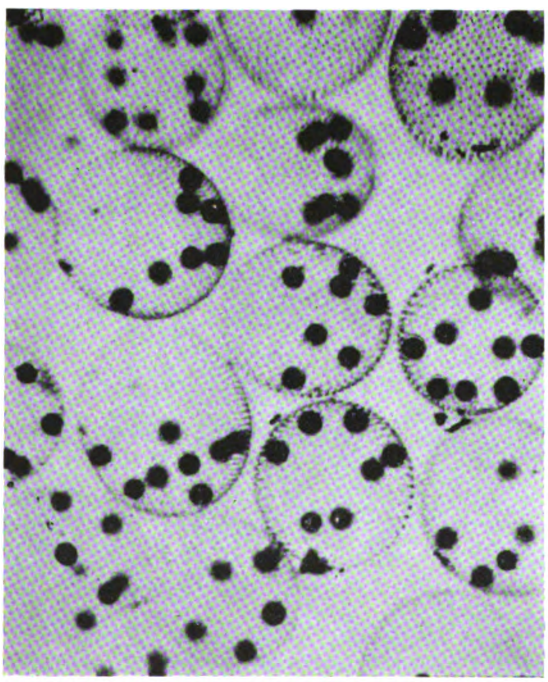


Photo: W. H. S. Cheavin, F.E.S.

VOLVOX GLOBATOR.

A green ball of many units, up to 10,000, embedded in a sort of jelly. It rotates in the water of ponds and canals and many botanists claim it as a plant. Daughter-colonies are seen inside the parent-spheres.

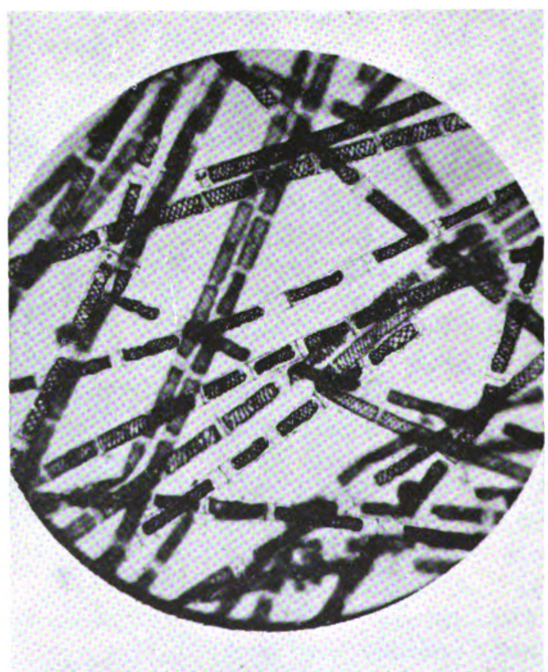


Photo: W. H. S. Cheavin, F.E.S.

FILAMENTOUS ALGÆ (Spirogyra).

Long threads of many cells, very common in pond-scums and the like. The green chlorophyll is arranged in a spiral which winds round the living matter of each cell.

and benumb small animals, but he noticed that fishes and whirligig-beetles reject the Hydra after once biting it. He tells us that the favourite food of his captives was the minute crustacean called Daphnia, but he also reports meals of minute worms and insect-larvæ. He describes one of the ways in which the Hydra moves about, looping along by alternately fixing the fore and hind ends of the body; and he figures a single tentacle suspending the polyp to the surface film! He tells how he cut a Hydra into four longitudinal strips—a triumph of manipulative skill—and got a perfect animal from each. He was also one of the first animal grafters, for he re-united cut-off pieces and got extraordinary monstrosities—such as seven-headed Hydras. One of the vignettes in his book, shows him turning a Hydra outside in. With a bristle he pushed the base inwards until it came out at the mouth. As the polyps may continue to flourish after this drastic operation, some explanation is necessary, for it means turning the digestive surface to the outside. The view of those naturalists—not many—who have succeeded in repeating Trembley's neat experiment is, that if you can turn a Hydra outside in, it turns itself inside out when you are not looking, and thus restores the original condition. And if the Hydra be spitted on a bristle so that the self-righting is impossible, what happens is that the in-turned outer layer disintegrates, but a new growth from the mouth region spreads over the out-turned inner layer and covers it up. The interest of this is that the outer layer, or ectoderm, cannot change into inner layer or endoderm, or conversely. Each layer has its own character, which cannot be radically altered.

Perhaps it may be thought that we have spoken in a somewhat callous way of cutting the Hydra into strips and so on. But it must be noted that there can be no question of cruelty or pain when we are dealing with an animal whose nervous system is as simple as Hydra's. For all that Hydra shows in that direction is a sprinkling of superficial sensory cells connected by fine fibres with a network of ganglion cells. Moreover, if Trembley's Hydra could be described as in any way happy, was it not multiplying happiness to cut it into four strips which grew into complete animals?

Photo: John J. Ward, F.E.S.

A DROP OF POND-WATER. (Highly Magnified.)

Drops of water from a densely peopled pond may show under the microscope a great variety of organisms, such as some water-fleas or minute crustaceans, some Rotifers and wheel-animalcules, some minute worms, several kinds of Infusorians, and various simple plants such as Diatoms and Desmids. But it is usually necessary to try many drops if one is to see much. This drop shows Volvox, Diatoms, Desmids, and more.

There are many very interesting facts in regard to Hydra, such as its two kinds of digestion

Photos: John J. Ward, F.E.S.

THREE MOVEMENTS OF THE COMMON HYDRA.

Extending its Body and Tentacles below Water.

The freshwater polyp or Hydra can move by fastening its tentacles, loosening its base, and then contracting its tentacles. It thus pulls itself forwards or upwards in a looping movement. When quite free it can move by contracting and relaxing its body. It is also able to glide on a leaf by means of amœboid processes from its basal cells. Lassoes ejected from stinging cells may also help in movement by adhering to objects in the water.

(intra-cellular and extra-cellular), its profuse budding when there is abundant food in a genial temperature and its liberation of these buds when a check comes, its production of a single egg at a time, and its occasional ability to fertilise its own egg.

Hydra is such a simple creature, with so much power of re-growing, that one would expect to find that it had a long life. It looks like the kind of animal that could continually recuperate itself from the effects of wear and tear, and thus avoid ageing. But the facts are rather against this. In an aquarium, at any rate, the Hydras are periodically subject to what is called "depression." For no obvious reason they become sluggish and cease to feed; they contract their body and tentacles, and lie low. They usually tumble off their attachment and lie as roundish or oval clumps on the floor of the aquarium. But after a rest of two or three weeks they revive and recommence normal activity with a new lease of life. In this periodic depression and recovery there is nothing that is inconsistent with what may be called bodily immortality, but, as a matter of fact, the depressions become more and more serious, and eventually fatal. It is very unusual for a captive Hydra to live for more than two years, but it may be that in natural conditions the duration of life is definitely longer. We wonder if the Hydra *must* die? May it not be like the one-celled animals, such as Amœbæ, that seem to be in the main exempt from natural death? From violent death there is of course no immunity.

The Amœba.

One of the commonest of freshwater animals is also the least familiar; it is the Amœba. And the reason for its not being so well known as it should be is simply that it is usually invisible to the naked eye. Strictly speaking, one should not say the amœba any more than the earthworm, for there are many different kinds of amœbæ, just as there are many different kinds of earthworms. Most amœbæ live in freshwater, creeping on the surface of mud, stones and water-weed; a few live in damp earth; and some are parasitic inside man and other creatures. Sometimes the number of species has been reckoned at about sixty; at other times it has shrunk to four; the truth is between these extremes. It has been shown that the different kinds of Amœba differ from one another in many details; that they are not more variable than many higher animals are; and that they are not in any very marked way modifiable by environmental influences.

One often envies a naturalist his discovery of a new animal of peculiar interest—the Okapi, Peripatus, the Lancelet, Hydra, the Duckmole, and so forth—and one cannot but envy Roesel von Rosenhof, who in 1755

Photo: John J. Ward, F.E.S.
BROWN HYDRA (*Hydra fusca*) EXTENDING ITS TENTACLES.
The Brown Hydra is somewhat variable in colour; the lower part of the tubular body is usually colourless. There are often six tentacles, which may be two or three inches in length!

discovered the Amœba. He not only described the animal, which he called "the little Proteus," he watched the protrusion of finger-like processes of its substance, and noticed that the external changes of shape were associated with an internal streaming—an observation of great importance, as we shall see. A typical Amœba is a complete animal condensed, as it were, into one-hundredth of an inch in diameter. It frequently changes its shape within certain limits, and it glides along in a way of its own. It engulfs food by enclosing its booty between two of the finger-like outflowing and inflowing processes—the "pseudopodia," as they are somewhat absurdly called. When drought sets in or other adverse conditions supervene the Amœba retracts its processes, rounds itself off, and secretes a protective cyst within which it may lie latent for a long time. When there is a return of moisture and prosperous conditions the Amœba emerges from its cyst with a new lease of life.

It has been common to speak of the Amœba as a shapeless blob of structureless living matter, and as if it were a primeval organism. But it is rather changeful than shapeless; it has an internal structure of considerable intricacy; and though its lineage probably goes back for millions of years it cannot be regarded as one of the first organisms. It has a long evolution behind it.

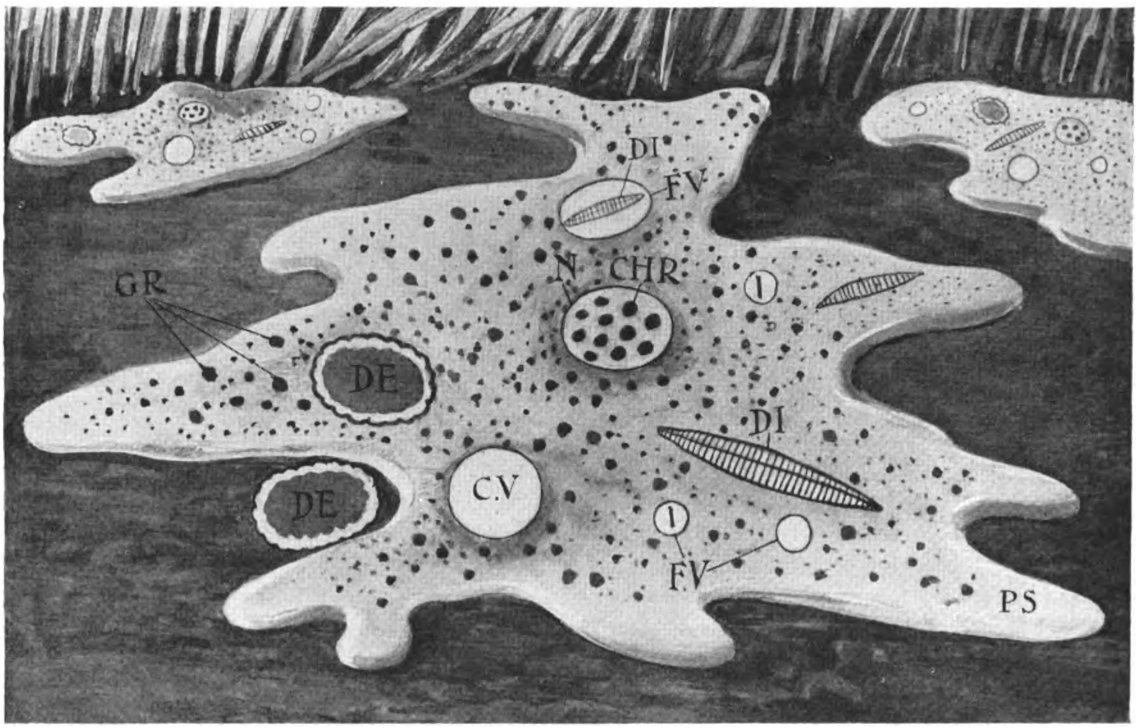
Floating in the somewhat emulsion-like substance of the Amœba there is a kernel or nucleus, and inside this there is a little world. The general substance outside the nucleus consists of living matter with inclusions which are non-living. There are granules and droplets, some with reserve materials and others with waste; there are bubbles of water surrounding food-particles; and there are two excretory bubbles or contractile vacuoles which expand and collapse continually, somewhat as if they were little hearts. They drain the living matter of its fluid waste and surplus water and open to the exterior. They disappear like burst bubbles and reappear in a few seconds in the same place. Around the margin the substance of the Amœba is firmer and clearer than in the interior, and under the high power of the microscope its margin shows a

Photo: John J. Ward, F.E.S.
GREEN HYDRA (*Hydra viridis*).
This species owes its green colour to the presence of minute unicellular Algæ, living as partners in its inner layer cells. It is often about half an inch long in body, and the same in tentacles, which are usually eight in number. But the size varies with age and degree of contraction.

fine radial striation which reminds one of the transverse markings on striped muscle fibres.

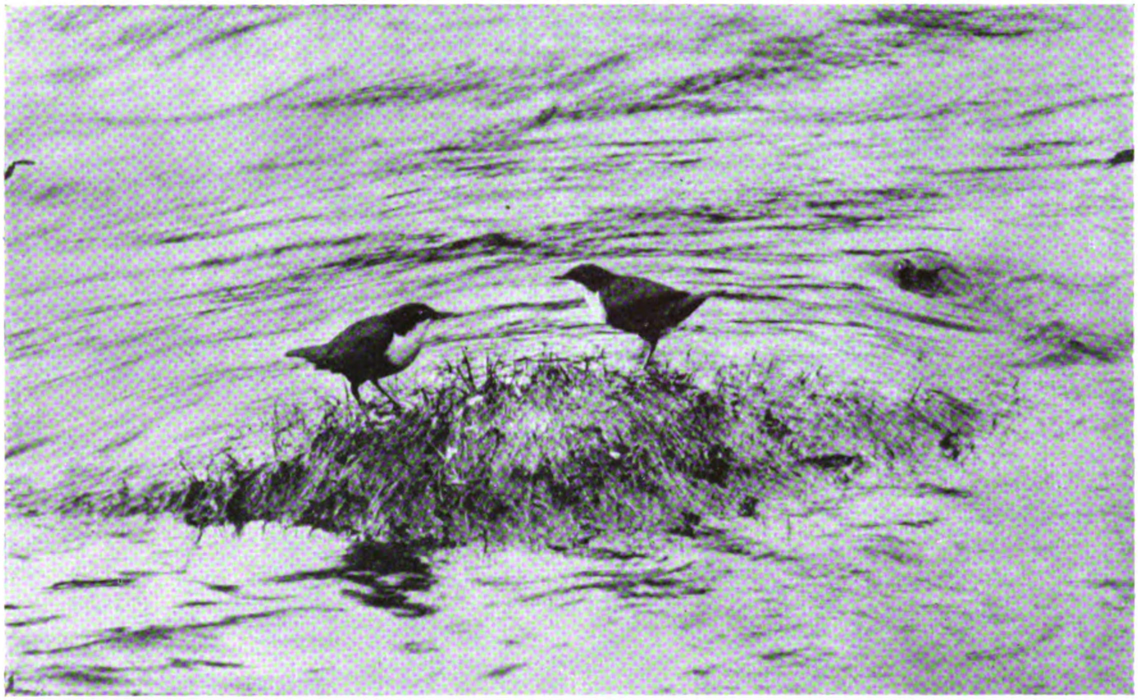
The Amœba is what one might call a many-sided animal, for it can engulf food anywhere, it can contract in any direction, it is susceptible to various outside influences on all sides. It draws away from diverse chemicals; it draws near to certain foodstuffs; it is attracted to surfaces on which it can creep. If an Amœba is isolated in the water, it sends out delicate processes on all sides as if groping for some solid basis. When we realise that the Amœba can move, feel, digest, breathe, and excrete just like an elephant, but all within the compass of a hundredth of an inch or less, our respect for the Amœba grows. The puzzle rises how it can do many different things at once in such a small space; and the solution must be that there is some sort of delicate ultra-microscopical partitioning within the living substance, like the walls separating the different rooms of a great chemical laboratory. This is what is attained in multicellular organisms by having cells. An Amœba is comparable to a one-roomed house in which all the domestic functions go on in orderly confusion, but a higher animal is comparable to a mansion with many rooms—kitchen and dining-room, lounge and laundry, store-room and drawing-room, and so forth. In other words, there is much division of labour in the higher animal, but there is relatively little in the Amœba. It follows that it is easier to study the physiology of the higher animal, for one function can be tackled by itself—the kidneys, for instance, are distant from the heart—whereas in the Amœba all the everyday functions are going on within a speck that is only a hundredth of an inch in diameter.

When food is abundant and income greater than expenditure the Amœba grows. It increases the amount of its living capital. But it does not grow indefinitely, for each kind of Amœba usually shows a limit of growth—as most animals do. It has an optimum size, when its volume of living matter or protoplasm is as large as the surface can readily keep alive. For as it is through the surface that the Amœba obtains



AN ENORMOUS ENLARGEMENT OF AN AMŒBA CREEPING ON THE MUD.

Amœbæ are simple one-celled animals of several different kinds, sometimes a hundredth of an inch in diameter, so that they are just visible to the unaided eye against a dark background. Each is a changeful drop of living matter with a nucleus, yet each is a complete animal N., Nucleus; C.V., Contractile Vacuole; F.V., Food-vacuoles; GR., Granules; DI., Diatom, engulfed as food; DE., Desmid, engulfed as food; CHR., Little Chromatin bodies in the Nucleus. The blunt outflowing processes or lobes are called Pseudopodia (PS).



A PAIR OF DIPPERS IN MID-STREAM (*Cinclus cinclus*).

A compact, short-tailed, white-breasted bird, often seen bobbing or "dipping" on the stones amid mountain-streams. It can fly under the water, and dives after caddis-worms, water-snails, small crustaceans, and the like. It destroys some of the enemies of trout fry.

Photo: Underwood Press Service.

NEST OF THE DIPPER ON A ROCK-FACE.

The nest is often on a rock beside a waterfall or in a hole beneath the spray. It is a big structure, made of moss or grass, but the real nest is inside, a leaf-lined cup of grass or sedge, about the size of a blackbird's. Four to six white eggs are laid in spring, and there may be two or three broods.

Photo: Oliver G. Pike, F.Z.S.

THE HERON (*Ardea cinerea*).

A resident bird in Britain, predominantly grey and dark slate in colour, with a strong yellow beak, and long greenish-brown legs. It has a length of about a yard and is one of the handsomest of water-birds. It feeds largely on fishes and frogs, but on much else, such as water-voles. The nests are usually in a colony or heronry, and consist of platforms of sticks, on tall trees in most cases.

food, oxygen and water, and gets rid of carbonic acid gas and waste, it is essential that increase of volume shall not outrun the increase of surface. At the limit of growth the Amœba divides into two, the simplest of all ways of multiplying. Occasionally it happens that an Amœba divides into many minute units or spores. And another event is that two Amœbæ sometimes combine their forces and become one. This is a reproductive process, but it is obviously not a process of multiplication.

As the Amœba has no true body to keep up, being merely a unit speck of living matter, it does not suffer from arrears of wear and tear. It does not get into debt as multicellular animals do. Moreover, its modes of multiplication are so physiologically inexpensive that it is not taxed as most animals are in starting another generation. Natural death was the price paid for having a body, and the Amœba seems to be exempt. Thus our respect for the Amœba increases, for it has organic immortality. It is probable that some of these duckpond Amœbæ which we examine with the microscope or may see with the unaided eye as minute whitish specks against a dark background have been living for millions of years. Of course, as we have mentioned, one individual divides into two individuals, and thus in a sense disappears; but we cannot speak of death when there is nothing left to bury!

The Amœba's movements still elude our understanding. They are not random movements, for the Amœba sometimes moves towards a definite goal. They are not "anyhow movements," for when an Amœba is not attracted to or repelled from any particular stimulus it moves in a spiral fashion, like many another animal or like a man swimming blindfold. When looked at very carefully, the Amœba flowing along—at the rate of some 600 microns (a thousandth of a millimetre) per minute—shows a sort of caterpillar-wheel-like mode of progression. Recognisable particles on the upper surface disappear over the front, and after a short time reappear at the posterior end, to begin once more a forward journey. It would be interesting if the Amœba gliding along or "rolling along" is actually a primeval anticipation of a "tank"!

According to Professor Asa A. Schaeffer's monograph on "Amœboid Movement" (1920) there is in the Amœba, as in some other slowly moving simple organisms, (1) a mobile surface layer, and (2) as in white blood corpuscles and the cells of some higher plants, a streaming in the deeper zones of the protoplasm. The locomotor energy is largely due to surface tension phenomena.

One of the most interesting facts known in regard to the Amœba is that it shows the beginnings of behaviour. It moves towards minute organisms such as diatoms and infusorians; it folds its protoplasmic arms around its victim, and literally gets outside it. Professor Jennings tells the story of a large amœba (A) which went on the hunt after a small amœba (a); for it must be admitted that amœbæ are sometimes cannibals. The large A overtook the small "a" and engulfed it, but "a" used an opportunity afforded by A's locomotion and escaped from its interior. Whereupon A turned from its course and pursued "a," which was captured a second time. But the small "a" had the will to live, which we take to be different from a surface-tension phenomenon, and it escaped again—more of an agent than Jonah! It was not captured a third time. So here at the threshold of life we find effective behaviour directed towards an end. If an Amœba the size of an elephant came "tanking" down towards us, we do not think we should stop to argue whether it had or had not a purpose.

In Praise of Swans

When we see swans swimming with half-raised wings, sinuously curving neck, and erected tail, swimming swiftly with powerful strokes of their black feet, and yet with superb unhasting dignity, we cannot but be thrilled with the magnificence of life. The swan is a poem, a picture, a harmony, and high-bred aristocrat besides. In plain prose, the swan is one of the most attractive of birds, and in daily life it insists on our respect. For though it may not be able to break our leg or arm, as is so often said, it can make us feel and look very small. It can certainly break a rib and kill a dog.

We should like to believe the tradition that Richard Cœur-de-Lion brought the swan to Britain. It is just the sort of thing he would do, for the swan is fearless and romantic. Our swan is a wild bird, *Cygnus olor*, in some parts of Europe; but most of those seen in Britain in places beyond man's patronage are "escapes"

that have become feral. It matters little, however, for domestication has left almost no mark on the Mute Swan. Perhaps it would be more correct to say that the swan has condescended to accept man's protection than to call it domesticated. In old days man's patronage was more marked, for it used to be customary to carve a design on the swan's bill and to pluck the pinions once a year. In places like the Norfolk Broads pinioning has been in great part given up, and the reward of this has been the sight of great flocks of swans on the wing. We have never ourselves seen flying swans except at a considerable distance, but we can appreciate the joy of watching the approach of the glancing wings and the thrill when a dozen birds alight on the water with a splash. Miss E. L. Turner pictures this in her fine book on "Broadland Birds." "Away over the marshes one catches a glimpse of what appears to be a line of milky white foam drifting over the reed-beds. Soon this takes shape as the swans advance and if one's ears are quick to hear, the noise of their rhythmic wing-beats may be heard a mile away—a clear, distinct sound, like the hum of a musical humming top." Mr. Coward compares the throbbing sound to the noise of horses galloping on hard ground. Unlike the Whooper Swan, which utters a loud, metallic, barking note as it flies, the Mute Swan saves its breath when it is on the wing. If it has a flight-call, as some authorities maintain, it does not often make it heard.

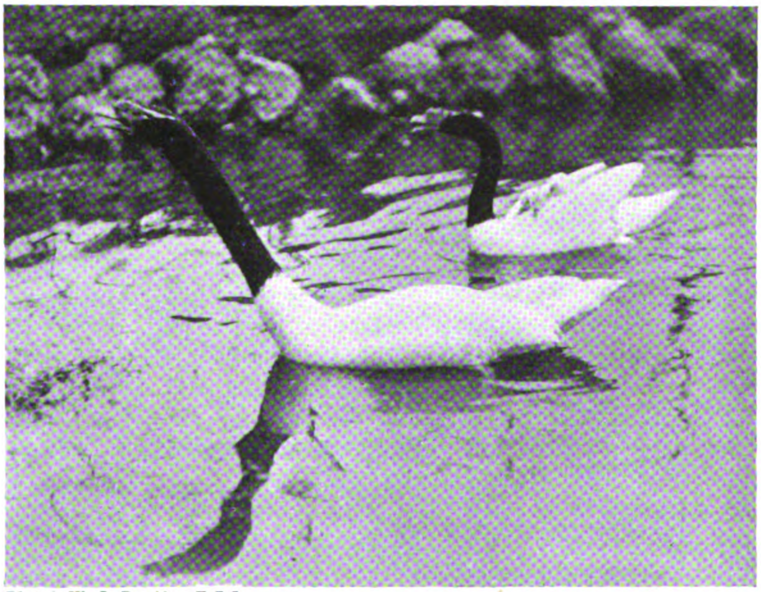


Photo: W. S. Berridge, F.Z.S.

BLACK-NECKED SWANS (*Cygnus melanocoryphus*).

This Swan extends from South Brazil and Chili to Patagonia and the Falklands, and is remarkable in the black colour of the head and upper two-thirds of the neck. The bill is lead-coloured with a red base and knob—the latter appearing in adolescence. In the photograph the swan that is further away has three cygnets on its back.

We hasten to add that the Mute Swan is far from being mute. Its daily life is not without conversation. There is an angry and ill-smelling hiss when the bird is provoked; there is a sort of churring growl that signifies protest and disapprobation; and, thirdly, there is what Yarrell called a "soft, low voice," rather plaintive and pleasing. But our swan would not have been called mute if it were not a *relatively* silent bird, and we may notice in this connection that there is very little profit in scientific criticism of the poets. "Swans sing before they die; 'twere no bad thing should certain persons die before they sing"; to criticise such neatness is folly. We would not criticise it for the world, and we do not like Michelet's suggestion that swans used to sing in Virgil's day in the sunny South, but lost their voice when they came to live in the sterner North. This is unusually matter-of-fact for Michelet, and it seems to assume the transmission of acquired characters, in which we do not believe.

There is something attractive in the old conceit of the swan's breaking its vow of silence in the twilight of its life. What can be the explanation of such a daring fancy?

The Silver Swan, who living had no note,
When death approached unlocked her silent throat;
Leaning her breast against the reedy shore
Thus sung her first and last, and sung no more;
"Farewell, all joys. O Death, come close mine eyes,
More geese than swans now live, more fools than wise."

As a matter of fact, a Pen or Cob swan is too much of a lady or gentleman to make such a stinging farewell as these lines suggest; but

Photo: James's Press Agency.

THE MUTE SWAN FLOATING GRACEFULLY DOWNSTREAM.

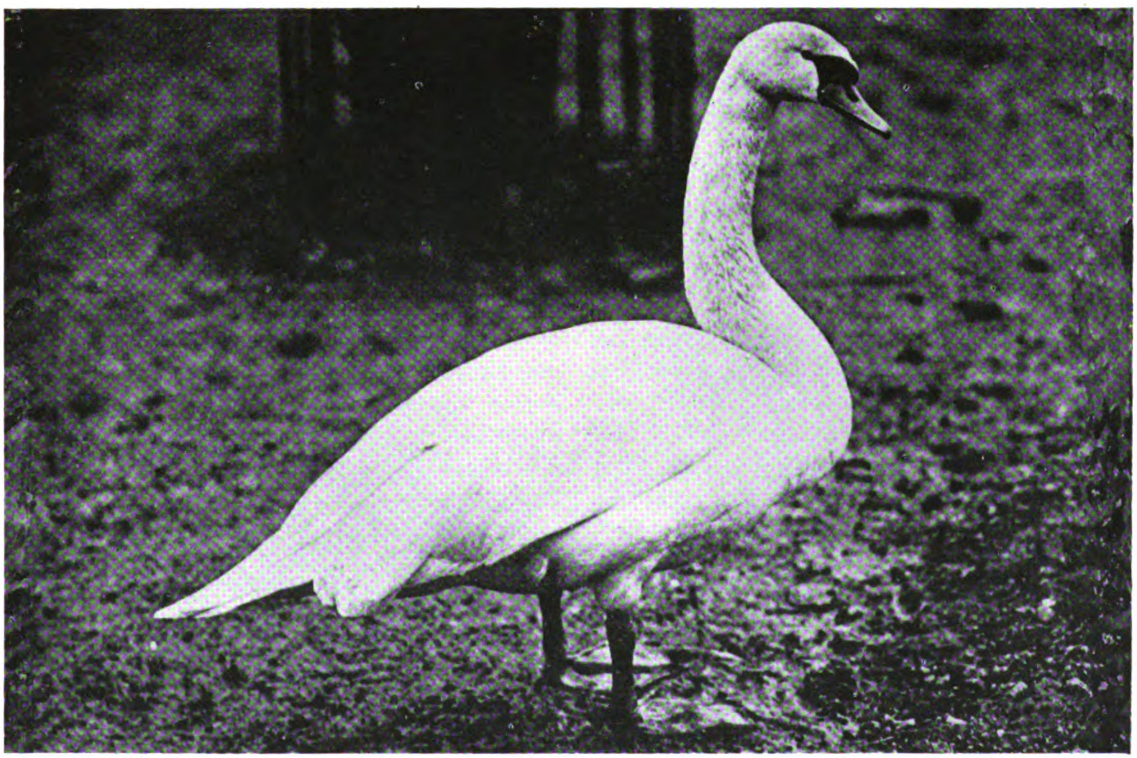
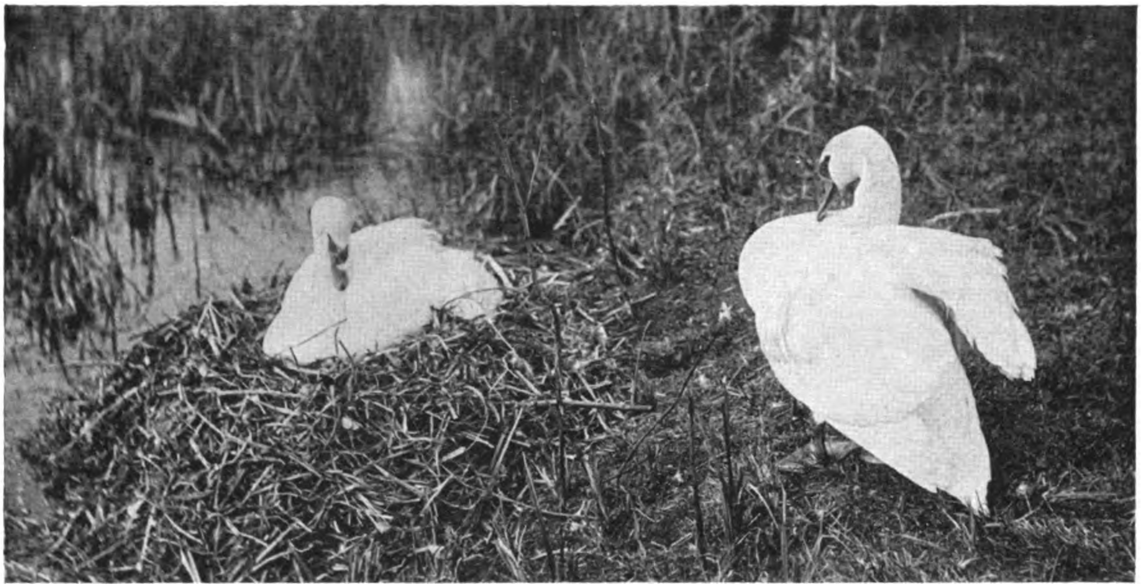


Photo: F. W. Bond.

THE MUTE SWAN (*Cygnus olor*) ON LAND.

There are three Swans in Britain; the Whooper (*Cygnus cygnus*) and Bewick's (*Cygnus bewicki*) are truly wild; the Mute Swan (*Cygnus olor*), is more or less domesticated. Besides having a black knob, the Mute Swan—far from being mute—is marked by the extraordinary graceful S-curve of the long neck.



SWANS AT NEST.

Five to twelve greenish-white eggs are laid in the large down-lined nest. Swans pair for life and the male helps in the brooding. He is also valorous in defending the nest. The photograph shows the female on the nest, while the male is preening himself close by.

how did the swan-song idea get so strong a grip? Mr. Hamerton suggests that the perfection of the swan prompted man to give a touch of uniqueness to its death. "Since the bird who could match the eagle in courage and man himself in longevity, and with whose beauty the king of the gods did not disdain to clothe himself, had never given the least sign of any musical talent or accomplishment; the fertile human imagination, always so unwilling to leave any hiatus in its ideals, invented that most poetical fable of the swan's song at the close of a songless life."

This is ingenious—almost as ingenious as the theory of the Queen of Navarre, who suggested that the bird's spirit, leaving the body through so long a neck, would produce musical murmurs! Perhaps, however, the Queen of Navarre was on the right tack, not exactly in explaining the swan's song, but rather its absence. For we believe that the reason for the Mute Swan's muteness, as compared with the vociferousness of the Whooper Swan or Bewick's Swan, is to be found in the fact that *it sings with its neck*, which is much more mobile than in the wild species.

What we mean may be illustrated by one of Miss Turner's delightful stories. Swans, it may be noted, are monogamous and very affectionate. The mother or Pen can hardly be induced to leave the young ones; and the father or Cob, though he often goes off for a little by himself, is devotedly solicitous and passionately fearless in defending his mate and offspring if there is any danger. On one occasion, when the Cob was in charge, the Pen did not return to the nest when she was expected. As hour after hour passed, the Cob became more and more uneasy and anxious, "continually rearing himself up and trumpeting." He paid no attention to Miss Turner's coaxing (they were old friends), and he refused to have any bread. After some hours Miss Turner set out in a canoe to search among the reed-beds, and suddenly met the Pen hurrying along head in air, hissing and scolding. "Hearing her mate call she responded, and I followed to see what happened. The Cob left the cygnets on the island and advanced to meet the Pen at a great pace. When they met much affection was shown on both sides. They rubbed bills, intertwined their long necks, and chortled with joy, then swam home side by side, and were greeted by the cygnets with shrill pipings." The cause of the Pen's belatedness is not essential to the story (she had an ugly cut on her bill, and had probably been having "words" with another proud Pen about the respective merits of their cygnets); our point is that the movements of the neck, which are very marked in the courtship, take the place of song, though not, of course, of speech.

The Mute Swan with which everyone is familiar is easily distinguished from the two wild species in Britain, the Whooper and Bewick's, both winter visitors to Scotland. For the Common or Mute Swan has a black knob and patch at the base of an orange bill, whereas in the two others the pattern is reversed, the bill being yellowish at the base and black towards the tip. The wild species have a stiffer neck, and they do not show that charming custom of swimming with the wings half-raised into a fascinating basket. It is worth looking at the breastbone of a wild swan to see how the windpipe descends right into the keel and makes a complete turn on itself. This is not seen in the Mute Swan.

The swan is a good lover and a good hater. As one would expect from its great beauty, it is very stable and long-lived; it has attained to harmony, and does not wilt or "sport." It is a very intelligent bird, as may be inferred even from such simple things as raising the nest if the water rises, and making a little gangway for the cygnets. Swans are model parents, as shown, for instance, in not allowing their cygnets to get to bed (though they sometimes go to sleep) before every feather is dry. To carry their family on their back is pretty, but to hold out a foot as a jumping-up step is genius. Finally, though we are not nearly done, swans are vegetarians. In fact swans are almost perfect except when they are walking on ice! Then they are geese.

When swans get their way they build a large nest of water-plants, which may be two feet high and even six feet in diameter. Its height can be added to if the water rises. In the middle of the big erection there is what might almost be called the inner nest, which is lined with down. Here are laid, usually in April, the 5 to 12 greenish-white eggs, about 4·3 by 2·9 inches. The Cob shares brooding with the Pen and the time required is between five and six weeks. As already stated, the swans mate for life, and the male is a devoted

SWAN AND YOUNG, AT NEST.

The nest is a large mass of plants somewhat roughly put together; but it is lined with down. It is often built near the edge of the lake among reeds and the like, or it may be on a little island. It is jealously guarded. The bird's magnificent spread of wing is well shown.

Photo: Neville Kingston.

SWANS AND YOUNG (*Cygnus olor*).

This species of Swan, wild in some parts of North Europe, migrates in winter to the Mediterranean shores and to Africa. It also breeds in Central Asia. Wild migrants may come to Britain, and domesticated swans may become wild or feral. The Mute Swan is known by the black knob or "berry" at the base of the orange bill; it is smaller in the female. The other British Swans have no knob.

father. If the nest is threatened he becomes very fierce, "busking," as it is called. This is well described by Mr. T. A. Coward in his delightful book, "The Birds of the British Isles," one of the best illustrated and most convenient of bird books. "In this terrifying performance the wings and scapulars (shoulder-blade feathers) are further raised, and the neck is drawn back until almost hidden by the wings; the bird forces itself forward in rushes with simultaneous strokes of its feet, ploughing up the water." The Cob is not only very courageous, he sometimes insists on taking more than his share of the brooding, a duty that spells patience.

The young when hatched are clothed in sooty-grey down, which is succeeded by dark sooty-brown feathers. These again are gradually replaced by white, but the change is not complete till the birds are over a year old. In rare cases, it seems, the cygnets are white from the first.

The Whooper Swan and the smaller Bewick's Swan have their representatives in North America, in both cases larger than the European forms. One of the two is called the Trumpeter, *Cygnus buccinator*, and has an expanse of wing of seven feet ten inches. It is said to be a somewhat truculent, quarrelsome bird, but in spite of this it is becoming very scarce. Its voice is compared to a short blast on a French horn. The other is the Whistling Swan, *Cygnus columbianus*, still found in some abundance; it has a yellowish patch, deepening almost into scarlet, on the bill, whereas the Trumpeter's bill is altogether black. Mr. D. G. Elliot describes the "swan song" of a stricken Whistler: "most plaintive in character and musical in tone, it sounded at times like the soft running of the notes in an octave."

After the painting by Philip Rickman.

THE BITTERN (*Botaurus stellaris*).

The Bittern is a heron-like bird with a beautifully marked buff plumage. It hides during the day and prefers running to flight when its retreat amongst the reeds is invaded. The booming voice of the male has great carrying power. Eels form a large part of the food.

In South America there is a small swan, called Cascaroba, but some authorities insist that it is a goose. It has black tips to the longest feathers of the wing, and reddish bill and feet. "It feeds on land, has a loud trumpeting cry, and a less noisy flight than the true swans" True enough, however, is the other South American swan, the black-necked swan, *Cygnus melanocoryphus*, which is black on the head and for most of the neck. In Southern Australia and Tasmania there is a handsome black or brownish-black swan, now becoming scarce. Its dark colour is relieved by snow-white pinions; "the coral-like bill is banded with ivory"; some of the feathers, such as those along the shoulder-blade, are beautifully curled. The divergence of Australia from other countries was emphasised by the discovery of this black swan (in 1697), and the bird was adopted as the armorial symbol of Western Australia. It is sometimes domesticated in England, and never fails to win admiration for its intrinsic beauty as well as for its curious contrariety.

It will be seen then that there is considerable variety among swans, though there are not many different kinds altogether.

They form a compact well-defined sub-family in the family Anatidæ, and they are not distantly related to geese which form another sub-family. The privilege of keeping swans used to be restricted in Britain to the larger freeholders, but it was gradually extended. Prof. Newton tells us in his "Dictionary of Birds" that "in the reign of Elizabeth upwards of 900 distinct Swan-marks, being those of private persons or corporations, were recognised by the royal Swanherd, whose jurisdiction extended over the whole kingdom." It used to be a big business to visit the important flocks in July or August each year, and put distinctive marks on the young birds. Professor Newton, writing in 1896, says: "The largest Swannery in England, indeed the only one worthy of the name, is that belonging to Lord Ilchester, on the water called the Fleet, lying inside the Chesil Bank on the coast of Dorset, where from 700 to double that number of birds may be kept—a stock doubtless too great for the area, but very small when compared with the numbers that used to be retained on various rivers in the country." Swans are not on the increase, but one wishes that all beautiful birds were as safe.

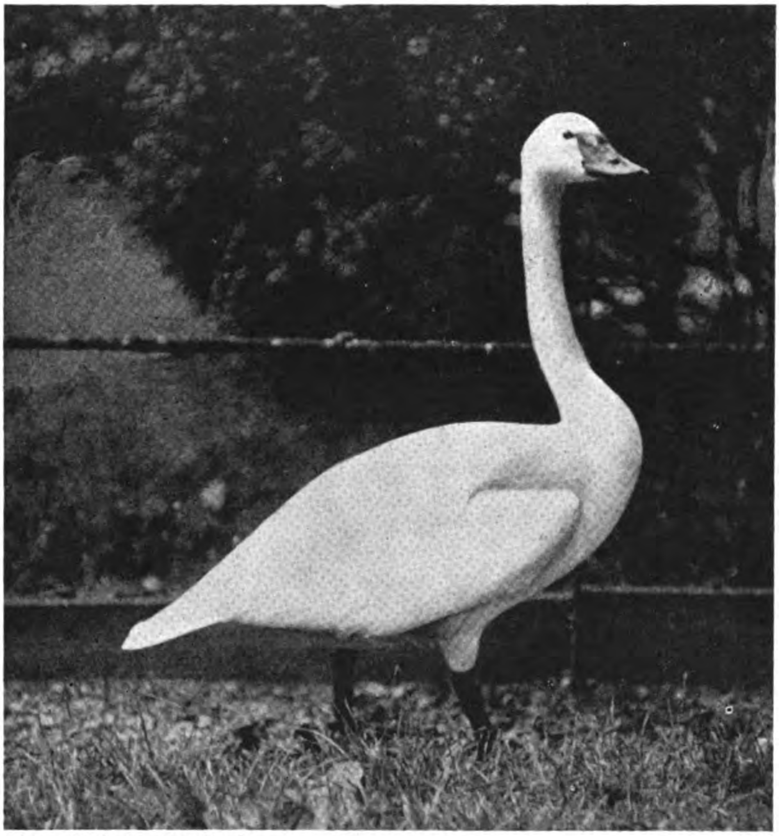


Photo: W. S. Berridge, F.Z.S.

BEWICK'S SWAN (*Cygnus bewicki*).

A winter visitor to Britain, breeding in the Far North of Europe and Asia. A sure mark is the yellow patch at the base of the short bill on each side. It is a very gregarious bird and may congregate in herds of several hundreds on the shores of salt-water lochs.

The Bittern of the Marshes

One of our rarest winter visitors is the bittern, which we welcome not only for its beauty and interest but as a bird that belongs to Great

Photo: E. L. Turner.

HOW THE BITTERN DEFENDS ITSELF: THE UPWARD THRUST OF THE YOUNG BIRD.

The bird often rests in a somewhat squat position, with its head on its shoulders, and the bill pointing upwards. This may rapidly give place to an aggressive and dangerous thrust, for the bird can suddenly shoot up to its full height and aim at the intruder's eyes.

Britain. For it used to be a common breeding bird in England and Southern Scotland, and there can be no doubt that when Neolithic man—a "long-headed, square-jawed, short but agile-limbed hunter and fisherman"—began exploring North Britain some 10,000 years ago, one of the most frequent striking sounds he heard was the bittern "booming from the mire." But slow changes of level, such as the "fifty-foot beach" indicates, reduced the extent of the swamps where the bittern was at home. As draining and reclaiming increased the bittern decreased. Moreover, the bird afforded good sport, and was more or less edible. Last, and worst of all, came the collector, and the bittern said good-bye as a breeding bird about the end of the 'sixties. In 1911, however, came the good news that Miss E. L. Turner and Mr. James Vincent had found a bittern's nest on the Norfolk Broads, and now the bird is coming back again, if people would only leave it alone. In 1918 Miss Turner knew of seven nests within four square miles, and in 1923 there were eleven. "The deep, resonant challenge of bittern calling to bittern across the great wide silence of the misty marshes heralding the gorgeous pageant of a Broadland dawn is now a familiar sound in many areas." This is most encouraging news, and we hope the bird will never have to say good-bye again. Extermination of a beautiful creature means dullness of outlook, but preservation follows when men awaken to the value of their entail. Therefore we venture on an appreciation of the bittern, owing much of course to Miss Turner's recently published "Broadland Birds"—a collection of fascinating studies of high scientific and artistic merit.

The bittern is one of the herons, a large bird, about two feet long, with a wing-length of about a foot. It is a study in brown, showing much golden buff, many black markings, and a white throat. The legs and feet are bluish green. Males and females are equally handsome and equally inconspicuous. For the main significance of the

colouring is that it gives the bird a cloak of invisibility. When the bittern stands stock-still among the reeds, with the tip of its bill pointing up to the sky, it has become a part of the scenery of the Broadlands. As Mr. Pycraft says: " Long lines of dark chestnut-brown running down the front of the neck simulate the shadows between the reeds, the lighter background and thick dark lines simulate dead reed stems." The bird melts into its surroundings. As in the American bittern and the little bittern there is a remarkable peculiarity in the absence of ordinary contour feathers on the back of the neck, which bears only loose downy feathers. But this region is partly shielded by an erectile fringe of long feathers, which extend along each side of the neck and meet on the back of the head. As in herons, there are some patches of " powder-down " feathers whose tips break off into minute platelets of horn-dust, believed to be of some use in plumage-dressing. The " powder " feels greasy between our finger and thumb, but that seems to be a mechanical illusion. It is quite dry, not oily. Even more of a puzzle is the " pectination " or comb-like appearance of the middle toe; but this occurs in many birds.

When the bittern is discovered, in spite of its self-concealing colouration, it abandons the erect posture and crouches, with its head drawn down on its shoulders, or with the neck outstretched horizontally. It broadens out its frills and raises its crest, and must be carefully watched. For it can suddenly shoot up to its full height and drive home its sharp beak with great rapidity and precision. It may strike its assailant in the eye. A bittern is reluctant to take wing and flies somewhat heavily, with owl-like silence, with wing strokes more frequent than a heron's. It can run with great rapidity, threading its way amidst the miniature jungle of the swamp.

One cannot help being a little sorry that the booming bittern does not thrust its bill into a reed, not even into the water or the mire. It booms with its bill pointing up to the sky, and it is the male who booms. Mr. Coward speaks of the call as " a deep, bovine, resonant note, certainly audible for over a mile. I have heard it all day and all night in May, and listened to

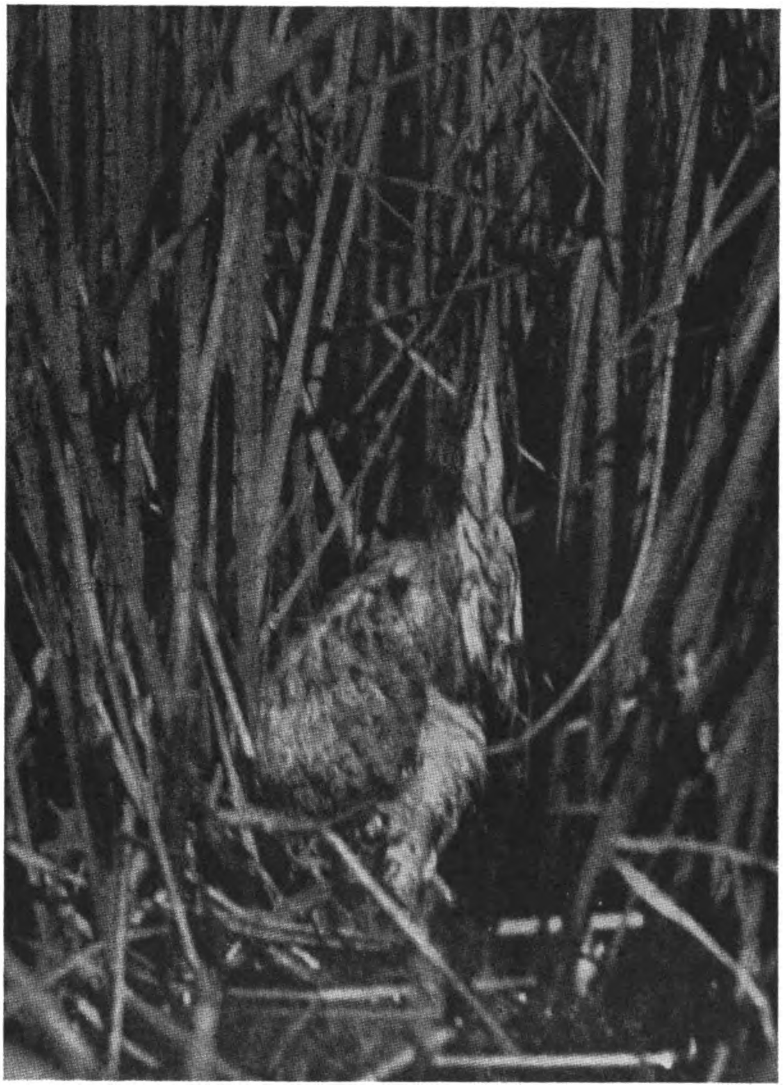


Photo: E. L. Turner.

CAMOUFLAGE: TURNING ITSELF INTO THE SEMBLANCE OF A REED.

When the Bittern raises its bill vertically and holds its thick neck erect it becomes almost invisible. As Miss Turner says, it is " transformed into the semblance of a bunch of reeds." Another attitude is crouching low with the neck outstretched among the decaying vegetation.

Photo: E. L. Turner.

NEST OF THE BITTERN.

The nest, now happily to be seen once more in Britain, is built of reeds and among reeds, and is sometimes a large platform. The eggs, usually five in number, have an olive-brown colour, harmonising with the environment.

it from a distance of three miles, and no lover of birds can help envying her an experience of a May night in the full moon, when "redshanks were yodelling, snipe bleating, lapwings calling, reed—and sedge—warblers singing as if their hearts would burst." "Beneath this riot of song and accompanying it like a deep bassoon was the booming of six bitterns challenging each other across the wide marshes." The male begins to boom early in February and ceases in mid-June. There can be no doubt that the boom is a call to the female, who sometimes answers back with a subdued but exciting "wumph." But the boom is also a challenge to other males, who answer back bravely. Corresponding to these two aspects of the booming are the male bittern's aerial displays and occasional aerial combats. To be distinguished from the booming are the raucous "aark" "aark" call-notes of both sexes; and very different also is the young bird's "bubbling" call for parental help, "which can be easily imitated by blowing through a straw into a glass of water."

The nest is a simple structure—a bed of dead reeds among the living reeds; and the female sits for about three weeks on the three to six olive-brown eggs. The young birds are strong and active in two or three days after hatching, and pugnacious from the first. They show a remarkable primitiveness in using their "hands" in moving across the nest or in supporting themselves when standing up. They require to be fed every hour from dawn to dusk, and the mother is kept very busy hunting for eels and other fishes. Miss Turner gives a lively description of the young bittern, standing about six

three or more birds answering one another. The boom is repeated three or four times in succession, with a one or two second interval between each note, then a pause of variable duration."

The word "bovine" for the boom is interesting, for it suggests the bittern's technical title Botaurus, the French name Taureau d'étang, and other designations referring to ox-like or supposed ox-like bellowing. Miss Turner tells of an acquaintance who refused to pass a certain corner of the Broad at night, because of a "gurt big bull a-bellowing on the maash"; but she says that the bittern's boom is not nearly so raucous as a bull's bellowing. She has heard

inches high when four or five days old, with long soft wavy tan-coloured down blowing over its face, with an elusive blue bloom on the bare patches of its skin, crouching and straightening, throwing itself on its back and kicking, thrusting aggressively with its bill, " more like an animated golliwog than anything else." " After the first week it is very difficult to round up the young. At the slightest approach of danger they walk off and hide in the reeds, where their soft brown and blue-green colouring harmonises completely with the dull brown sheaths of the reeds, and with the young reeds themselves." They can efface themselves without moving, and that is well, for they make a loud clamour when they are being fed, and they cannot fly till they are quite ten weeks old. Bitterns feed on small animals of the marshes, such as water-voles, frogs, newts, and fishes, and they do no harm. They may have some natural enemies, such as the marsh-harrier, but their wide geographical range from Ireland to Japan and throughout swamp-lands in Africa shows that they are securely established as long as their characteristic haunts remain. Which is our hope and prayer. Long may the bittern boom.

Salamanders.

Benvenuto Cellini tells us in his autobiography that one day, when he was sitting with his father before the fire, they suddenly saw a salamander basking in the midst of the flames. They both saw it plainly, but the father, being an educationist of the old school, gave the boy a sound box on the ear, so that he might remember the salamander for ever. The fire was a strange place for a salamander, which likes moisture and shade; but the

Photo: E. L. Turner.

YOUNG IN THE NEST.

The white-faced nestling Bitterns are clothed in brownish down, but show livid blue naked bellies. They keep up a quaint cackling, and though their colouring is very marked, it is anything but conspicuous. In the nest there is considerable use of the thumb of the naked wing to hold the young bird in effective position.

superstition lingered long that the clamminess of the creature enabled it to endure great heat and even to extinguish the flames.

So recently as 1716 the Philosophical Transactions of the Royal Society recorded that a salamander cast into the fire " swelled presently, and then vomited a store of slimy matter, which did put out the neighbouring coals." The only grain of truth is in the fact that a salamander in despair exudes a considerable quantity of the poisonous secretion, which it shares with the toad and many other amphibians, and that the muscular pressure may be so great that tiny jets are squirted from the skin-glands to a distance of nearly a foot.

The fire or spotted salamander is of wide occurrence in Europe, but it is not familiar to many. It is nocturnal in its habits and hides during the day in moist and shady places. After heavy rain large numbers often appear, for they cannot resist the earthworms that come up from the flooded burrows. As the skin is rich in poison-glands the salamander has few enemies, and many naturalists believe that the conspicuous livery—large yellow spots on a black background—serves to impress on daring experimenters among animals the fact of unpalatability or worse. In short, the yellow and black are " warning colours."

There is no fixed pattern in the yellow spottedness; indeed it is difficult to get two salamanders that are quite alike. Moreover, even in the same locality some have much more yellow than others. This probably points to individual *variability*. But Dr. Paul Kammerer, of the famous Experimental Biological Station in Vienna, has shown that there is also a high degree of *modifiability*. Variations are novelties coming from within as expressions of some idiosyncrasy in the fertilised egg-cell from which the animal develops; but modifications are indents impressed from without as the direct result of some peculiarity in the animal's surroundings, food, or habits. Now, on a yellow background the yellow spots of the growing salamander increase in area, and if there be a damp atmosphere there is a production of new yellow spots. So the salamanders get yellower and yellower every day. Moreover, Kammerer thinks that this modification in the direction of increased yellowness is in some degree transmissible, for the offspring start their life at a phase of yellowness nearly, but not quite, as advanced as that at which their parents left off. If this is confirmed, it has an important bearing on the much discussed question of the transmissibility of individually acquired characters.

High up on the Alps, even at altitudes of 9,000 feet, there lives the somewhat rare black salamander (*Salamandra atra*), a very interesting animal. The spotted salamander (*Salamandra maculosa*) is terrestrial, but it has to bring forth its gill-bearing young ones in streamlets; the black salamander, on the other hand, has emancipated itself from the water altogether. It may live in places where there is spray from a cascade or some drip from the rocks or moist vegetation, but it brings forth its young ones on land, and they are lung-breathers from their birth. This is plainly an adaptation to the Alpine heights. Now, it is a very striking illustration of the way in which animals in their development tend to climb up their own genealogical tree, that the unborn young of the black salamander, which are only two at a time, have three pairs of long red gills. But what can be the use of gills when there is no water? Very careful investigation has shown that the gills are pressed against the wall of the oviduct and absorb oxygen from the maternal blood. Moreover, they help to absorb nutritive fluid produced by a disintegration of eggs that have not developed. Some of this material may also be directly swallowed by the unborn larvæ!

Dr. Paul Kammerer found that if he kept the black salamander in warm and moist surroundings, it produced three young ones instead of two, and in subsequent seasons four or five or even six. Thus he got it to approach its cousin the spotted salamander, which brings forth an average of about fifteen or eighteen offspring.

Then this ingenious experimenter played the converse trick. He kept the spotted salamander in comparatively cool, dry surroundings, with the result that it produced at each breeding season fewer and fewer young ones, down indeed to two or three. But not only was the number reduced to that of the black salamander, the offspring were born at a somewhat similar stage of development. The gills were represented by little stumps! Here again there are striking facts to be considered in connection with the

vitally important question whether individually acquired modifications can be entailed on offspring. Thus we see that salamanders have a bearing on man's welfare, for he needs to know all he can about heredity.

The Toad.

As a type of the betwixt-and-between animals, recalling the time millions of years ago when backboned animals began to colonise the dry land, we take the toad, a literal Amphibian. It is a much misunderstood animal. No one likes to wear second-hand clothes, but how ready people are to garb themselves in second-hand opinions! One of these is suggested by Juliet's phrase, "the loathed toad." For this admirable amphibian undoubtedly suffers from a deeply rooted traditional prejudice, which disappears whenever one looks at the toad for oneself and with a fresh eye.

Even a good naturalist like Pennant of the eighteenth century wrote terrible nonsense about the toad: "The most deformed and hideous of all animals; the body broad, the back flat, and covered with a pimply dusky hide; the belly large, swagging and swelling out; the legs short, and its pace laboured and crawling; its retreat gloomy and filthy; in short, its general appearance is such as to strike one with disgust and horror."

One cannot expect every animal to be like a butterfly, and it is not claimed that a toad is as handsome as a squirrel. There is difficult beauty and easy beauty, and the toad's is a little difficult. But if we could get the verdict of an unpacked jury, including a few artists who are experts on beauty, it would be unhesitatingly in favour of the toad. It is a bit of a grotesque, of course, but it is an artistic unity.

The shape is compact and well-proportioned; the skin is wrinkled and warted, reminding one of the rugged weather-beaten face of an old ploughman. The colours are pleasing. Dr. Gadow describes them as "olive grey to dark brown above; the under parts whitish, often with a brown, yellow or reddish tinge." There are many colour-varieties, and even an individual can change considerably according to its moods and haunts. The eyes are undeniably fine,

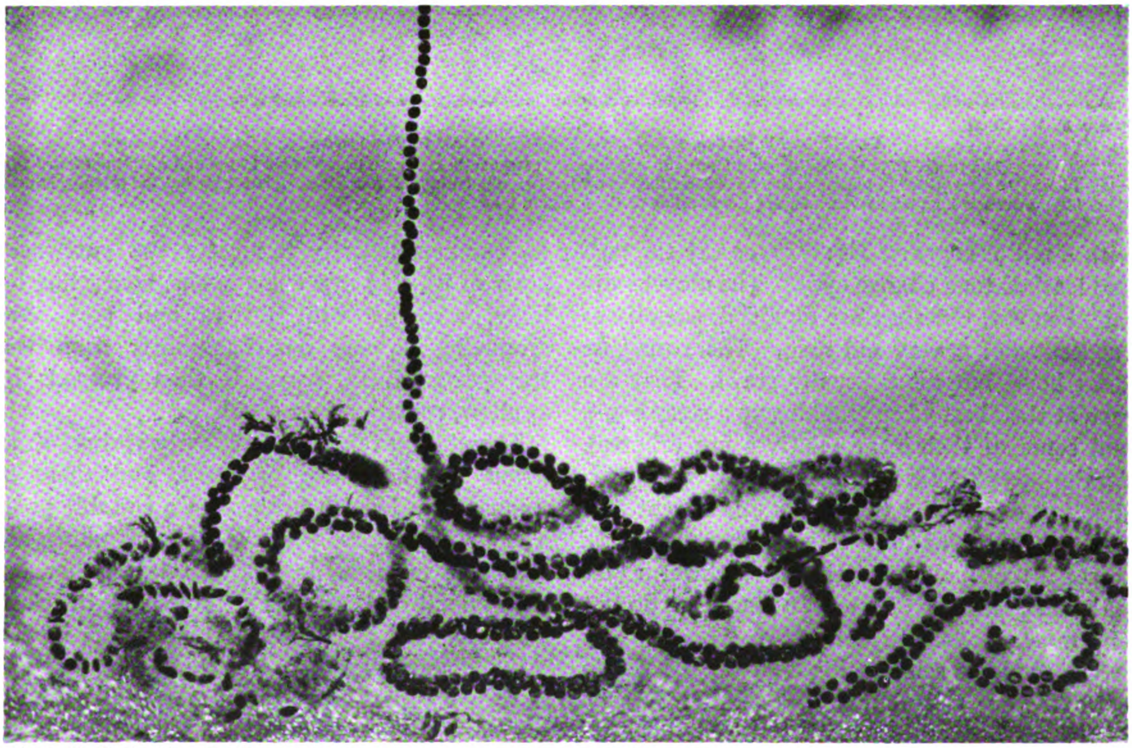


Photo: W. S. Berridge, F.Z.S.

SPAWN OF THE COMMON TOAD (*Bufo vulgaris*).

The dark-coloured eggs, towards a twelfth of an inch in diameter, are expelled in two strings, each with a double row. The strings swell to be about a quarter of an inch across, and they may be ten to fifteen feet in length. From 2,000–7,000 eggs may be liberated at once, and they are fertilised as they are expelled. The strings are wound amongst water-weed.

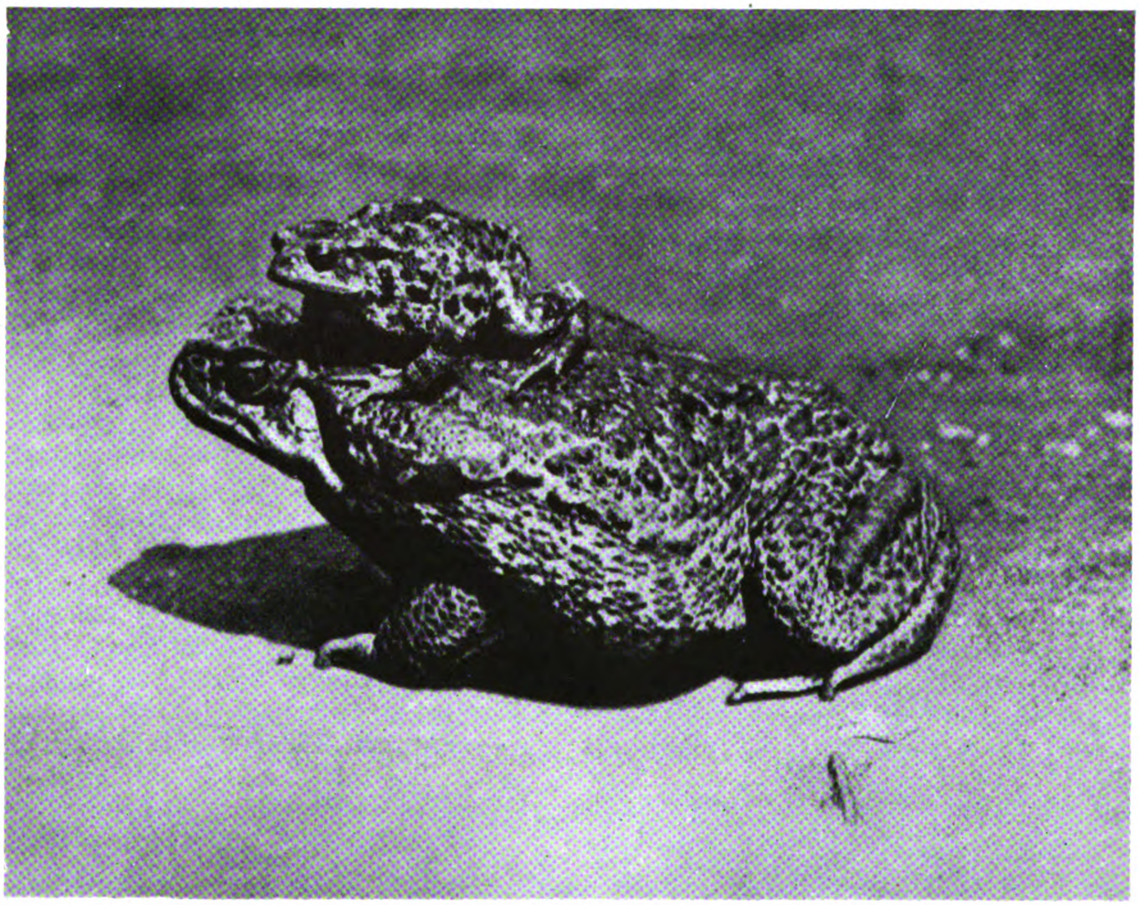


Photo: F. W. Bond.

GIANT TOAD (*Bufo marinus*) AND COMMON TOAD (*Bufo vulgaris*).

The Giant Toad ranges from the Antilles and Mexico to Argentina. It frequently reaches a length of six inches and a width of four. The voice of the male, strengthened by a resonating sac, is described as a "loud snoring bark," but it is a "tremulous bass" at the breeding season. These big toads show hopping movements, not the crawling of the common toad.

with a red or coppery iris: "Some say the lark and loathed toad change eyes." The movements may be slow, but they are dignified, sometimes suggestive of a very old man. There may be short hops, but toads usually crawl. They are seen at their best when climbing up a steep bank, and some of their near relatives are arboreal. At the breeding time they swim strongly. The shooting out of the rosy tongue is a neat and effective trick, and we like, we must confess, to see a toad poking a gripped earthworm into its mouth with its fingers. In short, we do not find much that is ugly in a toad.

The toad is a self-effacing animal. It hides in holes by day; it hunts at dusk for insects, earthworms, and small snails. It lies in a lethargy through the winter, burying itself in loose, dry earth or in the midst of withered leaves, perhaps in the hollow stump of a tree. During its summer activity it moults the outermost layer of its skin every few weeks, contorting its body, scraping with fingers and toes, and gradually slipping out backwards from the transparent husk, which it then proceeds to swallow, rolled up into a pill.

The pairing takes place in early spring, often about the beginning of April, and there is frequently a longish journey to a suitable pool. The ardent males, who are far more numerous than the females, fight with one another for possession, and are very prolonged in their embrace. Dr. Boulenger compares their cry to "the distant barking of a little dog"; Dr. Gadow compares the female's weak response, which goes on day and night, to "the whining bleat of a lamb."

The eggs, which may number 2,000–7,000, are laid in two double strings, sometimes ten feet

long; they are fertilised as they are laid; and they are entangled among water-plants by the movements of the coupled pair. In about a fortnight the tadpoles emerge, but nearly three months are required before the metamorphosis is completed and the miniature toads leave the water. They are not quite three-quarters of an inch in length, and more agile than their parents. They hide among grass and in little holes in the ground, and when a summer shower interrupts a time of drought they sometimes appear in such numbers that credulous people insist that it must have "rained toads."

The Common Toad (*Bufo vulgaris*) may be distinguished from the Common Frog by its warty grey-brown skin, by having no teeth, by its less-developed web between the toes, by its much shorter hind-legs, by its crawling and climbing, by its nocturnal habits, by the laying of the eggs in strings, and in many other ways. One must remember, however, that there are toads and toads. Within the genus Bufo alone there are about a hundred different species, distributed all over the world except in the Australian region and Madagascar, and some of these are not like our Common Toad. Thus the African Jerboa Toad has very long and slender limbs. Moreover, there are some burrowing frogs that are very toad-like.

Thus, in the long run, to find the right answer to the question, "Why is a toad not a frog?" we should have to pry into technicalities which enter into the very bones.

The second British toad, the Natterjack (*Bufo calamita*), has large vocal sacs, a very loud croak, yellow eyes, and considerable brightness of colouring. Its hind-legs are so short that it cannot hop, but it can run at a fair speed. Unlike the Common Toad, it occurs in Ireland as well as in Great Britain.

The toad is said to be "a slimy creature, spitting venom," but it is rather dry-skinned and it cannot spit. It is said to suck the udders of cows, but it cannot suck, and it does not

Photo: Stanley C. Johnson, M.A.

BRITISH NATTERJACK TOAD (*Bufo calamita*).

This little toad, one and a half to two inches in length, occurs in sandy places in England, Wales, and Ireland. It is more active than its larger relative, and runs with little jerks like a mouse. In spring the male makes a loud courting sign and dilates his bluish throat. Other males take up the cry, and the chorus can be heard for a mile.

drink. Most of the popular beliefs about toads are clotted nonsense, and no one has ever verified the zoological part of the familiar lines :

" Sweet are the uses of adversity,
Which, like a toad, ugly and venomous,
Wears yet a precious jewel in his head."

It is a pity that an unoffensive creature, likeable in many ways, timid and tamable, apparently able to recognise a friend, should have been libelled so basely.

It is always of interest to raise the question of survival, and the answer in the case of the toad must be found in its quiet, elusive ways, its burrowing, its crepuscular activities, and its capacity for lying low without food in the winter. But it has another quality that is of survival-value, namely, the abundant secretion of poison from the skin-glands, especially from a large cluster behind the eye. What we see is a creamy fluid which oozes out when the animal is stoned. It includes an irritant volatile poison called phrynin ; and as this makes the toad's skin very unpalatable, it is better than any armour.

LXV
ANIMAL COURTSHIP

IN a great variety of ways there is love-making among animals, and we cannot wonder at the variety since each kind of creature is itself and no other. In its courtship, just as in its nest-building, the bird expresses itself—its individuality; and related kinds, such as lapwing and oyster-catcher behave in different ways. It is in spring that courting is commonest, and the courting is in a sense the creature's spring—a renewal or renaissance of body and mind. Perhaps Tennyson was not so happy as usual when he wrote :

" 'Tis in spring the wanton lapwing gets
himself another crest,"

for the lapwing is not " wanton " and both sexes have an erectile crest, though it is stronger in the male bird. But perhaps this is hypercritical, for everyone knows that spring is the chief time of courtship.

The significance of courtship is to express love and desire, but we must not think of animals as if they deliberately ruled their conduct in reference to an end, as human beings do. They are full of passion and desire for possession, and they express themselves in many different ways which are, as it were, prescribed by the inborn inheritance. The details vary with the individual, but the broad lines are the same in all the members of the species. They form part of the instinctive equipment. What they do in the way of singing or display, dancing or fighting, is the outcome of age-long sifting of those self-expressions that proved most effective in exciting the interest and the admiration, the sympathy and the passion of the desired mate. In 999 cases out of 1,000 it is, of course, the male who woos, but there are quaint exceptions, as in the Grey Phalarope, where the female courts and the male broods.

In taking a review of animal courtship we should naturally begin with mammals, the class to which we ourselves belong. But the palm of love-making belongs to the birds, who are more artistic. What strikes one first is the great variety of method within a single class. Pre-eminently there is song, mostly confined to the males, music to us, music to the ears for which it is meant, endlessly varied yet always saying the same thing : " Hither, my love ! Here I am ! Here. Lo, the winter is past ; the rain is over and gone ; the flowers appear again upon the earth ; the time of the singing of birds is come, and the voice of the turtle is heard in our land."

Courtship among Birds.

We must not think lightly of the most beautiful courtship in the world—the invocation in the bird's song !

" 'Tis the merry nightingale that crowds and hurries and precipitates with thick fast warble

his delicious notes, as he were fearful that an April night would be too short for him to utter forth his love-chant, and disburthen his full soul of all his music."

Part of the significance of courtship, besides expressing desire and exciting a sympathetic resonance of passion, is to strike the psychical note, to bind the sex-sick mates into love as well as fondness, to rivet linkages that will outlive passion, *marrying* the mates into loyal partners and parents, loyal sometimes for their lifetime. Not that the courting creature ever thinks of these "ends," yet they are the accruing advantages that have justified in the course of millennia the unconscious elaboration of the courtship ceremonial. Besides singing, twittering, cooing, crowing, and calling there are appeals to sight and touch and even memory. There is a display of plumage and ornaments, of agility and grace in strutting, parading, fluttering and flying, and in fighting with rival males. Common also are oft-repeated rhythmical movements, as in bowing, curtsying, swaying and dancing.

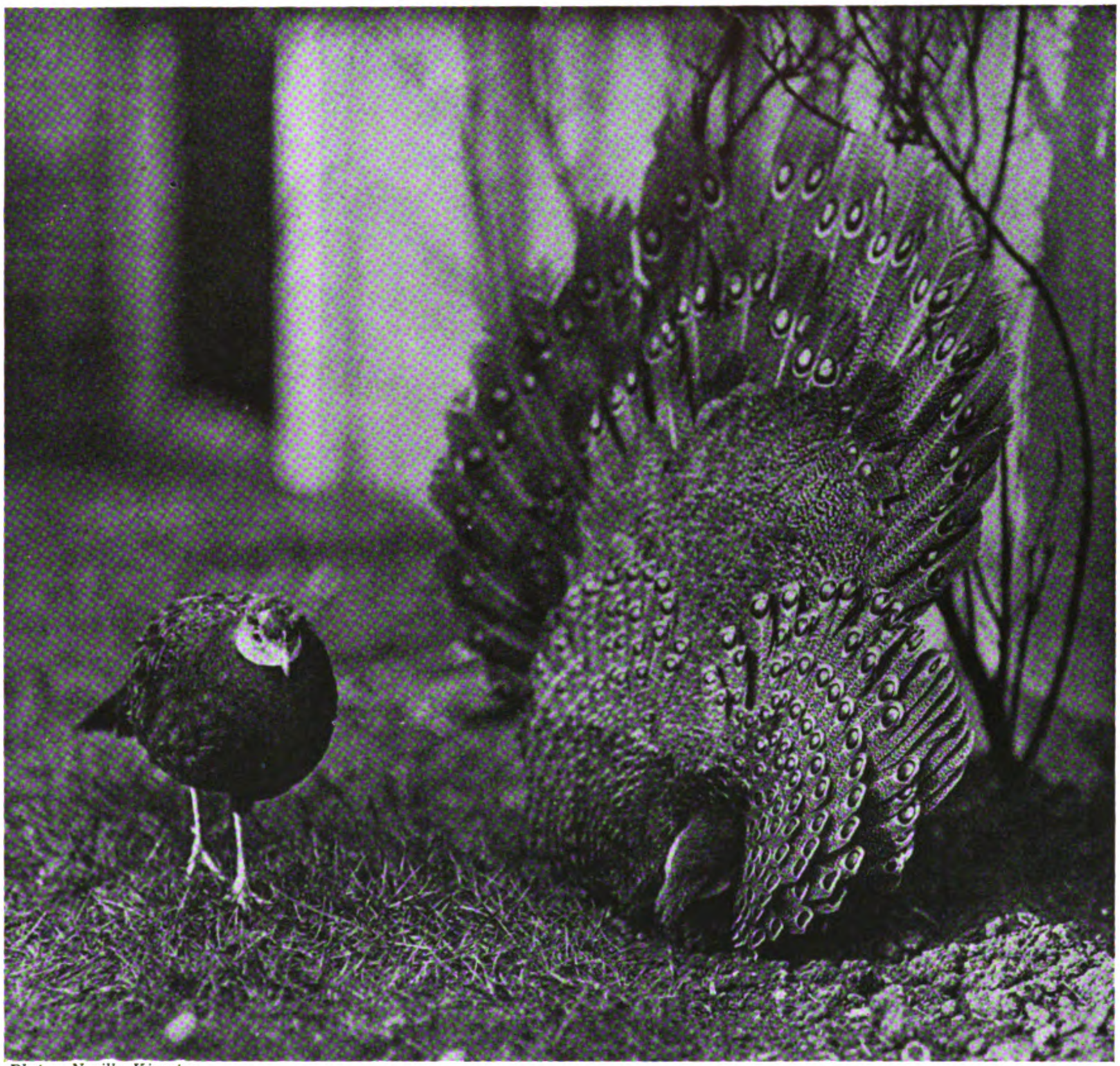


Photo: Neville Kingston.

PEACOCK PHEASANT (Polyprecton) DISPLAYING TO THE HEN.

Large tail-coverts, arising as in the Peacock above the root of the tail-feathers proper, are palish-brown with a green and purple "eye." But the true tail-feathers are also very gorgeous, and bear "eyes" surrounded by a circle of glossy black. The male shows off his brilliance before the more soberly coloured female, which has a relatively simple tail. In the wild state, in Assam and elsewhere, the Peacock Pheasant is very shy, but it does in some degree submit to domestication.

But love may strike the harp on even subtler

Photo: D. Seth-Smith.

DISPLAY OF THE ARGUS PHEASANT (*Argus giganteus*).

This gorgeous bird is a native of Sumatra, Malacca, and Siam. Its body is not much larger than that of an ordinary barn-door fowl, but the total length of the male, when the long tail-feathers are included, may be five feet. The wing-feathers, that form the gorgeous fan, may be three feet in length. The female has none of these very long feathers, and no eye-like markings.

strings, rather beyond our intellectual hearing, as when the Great Crested Grebes offer one another gifts of water-weed, or when the Bower-birds decorate their courting runs with brightly coloured flowers and fruits and shells. But whatever be the mode of courtship among birds, it is almost always artistic. Here and there we get a glimpse of an ugly feature, but on the whole the courting behaviour is beautiful. There is selection for health and vigour, for grace and agility, for musical gifts, and other æsthetic qualities. Not that these are analysed out by the female bird who chooses; it is rather that the successful or most successful suitor is the male whose *tout ensemble* of gifts and graces most interests and excites the coy hen.

Among the recent studies of bird-courtship the most scientific are those of Professor Julian Huxley. Some years ago he gave a careful description of the elaborate behaviour of the Great Crested Grebe, whose sex-performance includes waggling and swaying, bending and shaking, a cat-attitude of display, a "ghost dive," a "penguin dance," and an offering of water-weed gifts. The conclusion the observer came to was that the courtship ritual establishes emotional bonds between the lovers. "The courtship ceremonies serve to keep the two birds of a pair together, and to keep them constant to each other."

A more recent study, along with Mr. F. A. Montague, deals with the Oyster-Catcher, a very attractive bird of the sea-shore and the riverside, with black and white plumage, orange bill, and pinkish legs. There is a remarkable "piping performance" in which trilling and movement are combined. In variable numbers, the birds adopt a characteristic attitude: "The head and bill directed straight downwards, the bill held open and very slightly vibrated, the neck thrust forward so that the shoulders show up with rather a horsey look." Sometimes the whole body is bobbed up and down at intervals; sometimes there is a trotting dance; but the piping may occasionally occur when they are flying or when they are standing

in the water. Both males and females may pipe, but one of a pair may be more energetic than the other. This is probably the male, but the sexes are externally indistinguishable.

What Professor Huxley has shown in this case is that the piping performance has more than a courtship significance. It may be an expression of any strong emotional excitement except fear. It may be exhibited by a single mature bird or by an aggressive bird; it may also express jealousy—territorial as well as sexual. Originally associated with various forms of emotional excitement, the piping has become particularly linked to courtship. It may be stimulative or provocative, and there is evidence of its being infectious, one vigorous piper making another tune up. It may also serve to make other cocks and hens aware of how the wind of sex is blowing.

Another wading bird that Professor Huxley and Mr. F. A. Montague studied is the Black-tailed Godwit. The male has a ceremonial in which he rises rapidly to a height of one hundred and fifty to two hundred feet and then suddenly changes both his call and his flight. The quick beating is replaced by slow, clipping strokes, somewhat like those of a strong-winged butterfly. The tail is spread and twisted from side to side; the body is tilted with the tail and the bird heels over, thus rolling from side to side in the air—sometimes for over a mile in a straight line! Then comes another sudden change. "The rolling flight and the dissyllabic call stop as they began, simultaneously: for a moment the godwit glides in silence with stiffened wings. Then, without warning, it nose-dives towards the ground, with wings and tail almost closed. About fifty feet from the ground the wings are opened, and the godwit side-slips in all directions, like a rook when 'shooting' before wet weather."

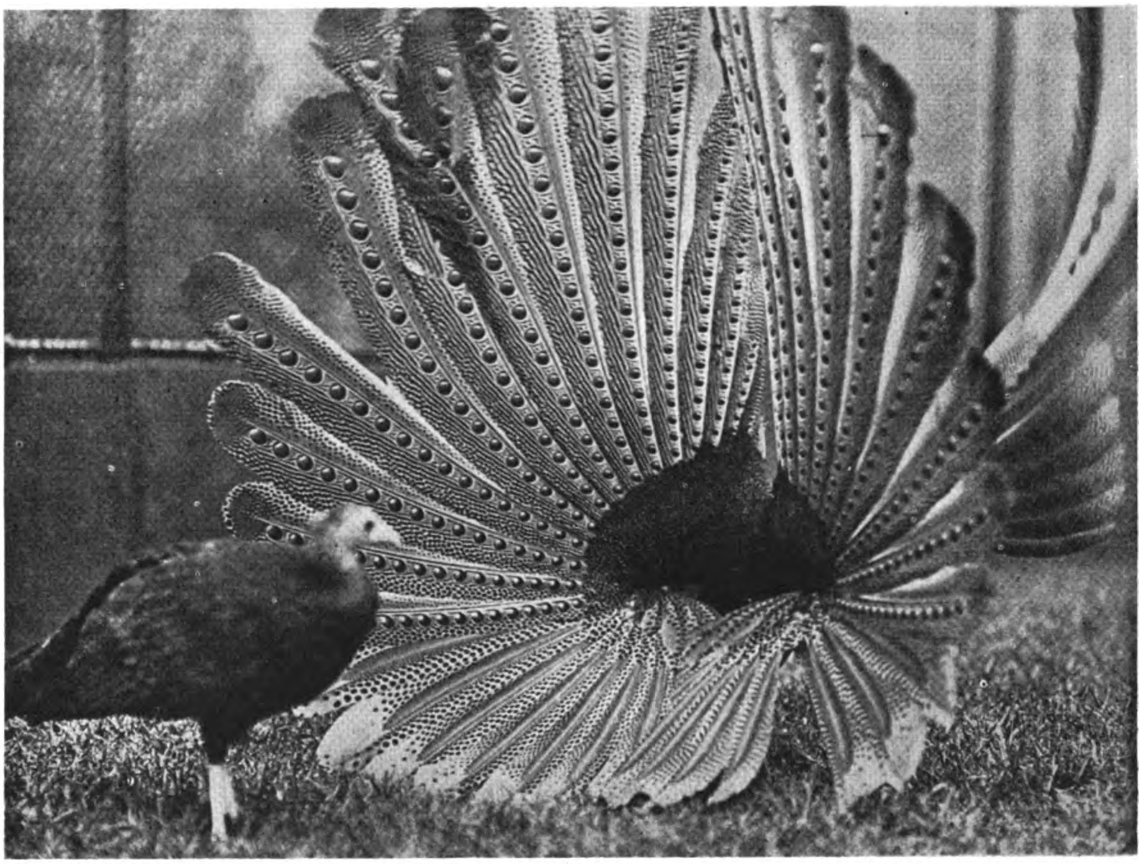


Photo: Neville Kingston.

DISPLAY OF THE ARGUS PHEASANT.

In the male's display the wing-feathers are spread out as an almost upright circular fan in front of the bird, and before the eyes of the hen. To see his desired mate the cock-bird may push his head out between the bases of two of the wing-feathers; his eye may be seen in the photograph to the right of the beak, which shows as a white spot to the left of the centre.

But in addition to the male's ceremonial flight there is a joint flight of both sexes, who call to one another as they fly. There is also a strutting performance in which the male spreads out the beautiful black and white fan of his tail. Another quaint piece of behaviour is the "scrape ceremony," usually, but not always, confined to the male. The bird runs to a slight depression in the ground, crouches with raised tail and slightly open wings, and then screws its breast against the ground, as though smoothing out and rounding off a nest-like scrape. This is probably a "suggestive" ceremony.

Professor Huxley's scientific studies of these love mysteries are very important. They show the subtlety and individuality of the courting behaviour. Can we wonder that birds are so beautiful when their love-sifting (or sex selection) has so much reference to vigour, agility, and æsthetic qualities, the ecstasy of health, in short?

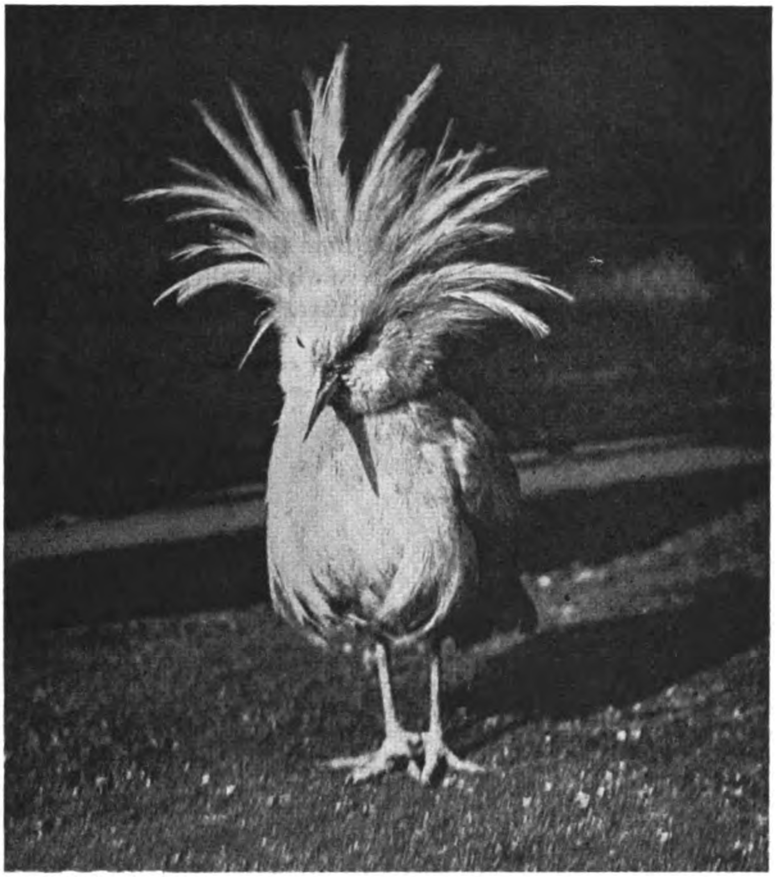


Photo: F. W. Bond.

KAGU (*Rhinochetus jubatus*) DISPLAYING.

This is the sole representative of a family (Rhinocetidæ) related to the bustards and sun-bitterns. It is a native of New Caledonia, a bird about the size of a fowl, with large head and eyes, heron-like bill, and slaty-grey plumage. There is a long erectile whitish-grey crest, and the male indulges in a fantastic dance at the courting time. The wings and tail are spread out so that the rest of the bird is almost hidden.

We miss part of the meaning of animal courtship if we do not appreciate the elaborateness to which it may attain. Even in a very familiar bird like the lapwing or peewit, there is a wonderful intricacy in the love-making. The males show an almost reckless abandon in their aerial dances, with nose-dives and somersaults interspersed; we all know the prayerful cries and the "wing-music"; there is posing and display on the ground and the excited making of "scrapes" or "cock's nests." It is no doubt difficult to draw the line between courting and *joie de vivre*, but who can be blind to the fact that the cock-peewit is very much in love? What are called "cock's nests" are regarded by some generous naturalists as devices for distracting attention from the real nest; but this is too subtle. The male peewit makes them by energetically working his body in the ground till there is a slight depression, and he often shows off in so doing. The coy female sometimes becomes interested in what he is doing, and draws near to inspect. That gives the male more opportunity to show her what a fine fellow he is! It may be that the resemblance of the scrape to a true nest serves as a sort of suggestion to the female bird. In some cases it may even awaken memories.

Courtship among Mammals.

There is more strength than art in the courtship of mammals, and there may be no courtship at all. There are sex-calls indeed, as we know in the cacophonous caterwauling of the cats on the roof, but these seem a sad bathos

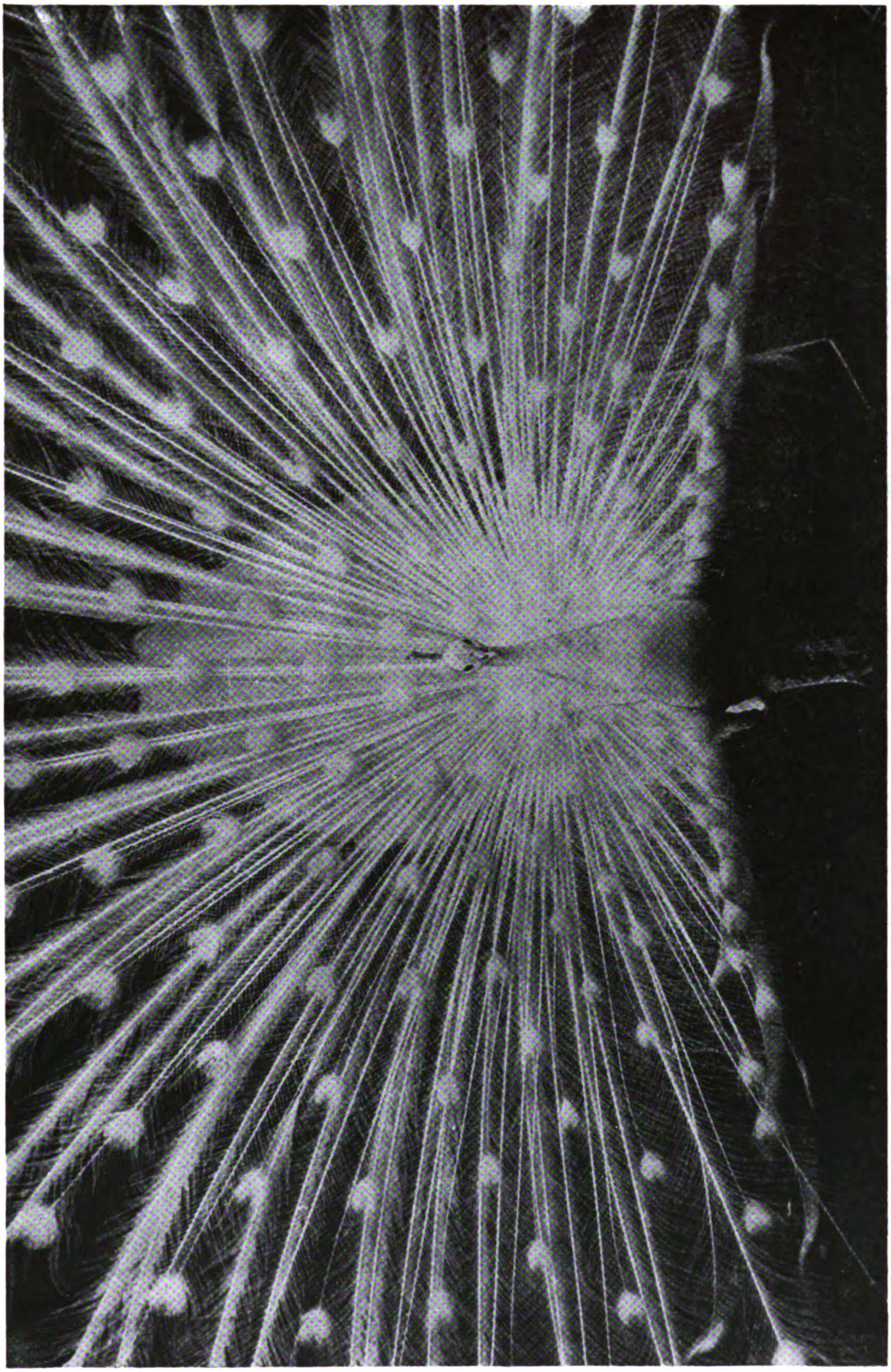


Photo: A. H. Hall.

DISPLAY OF THE WHITE PEACOCK.

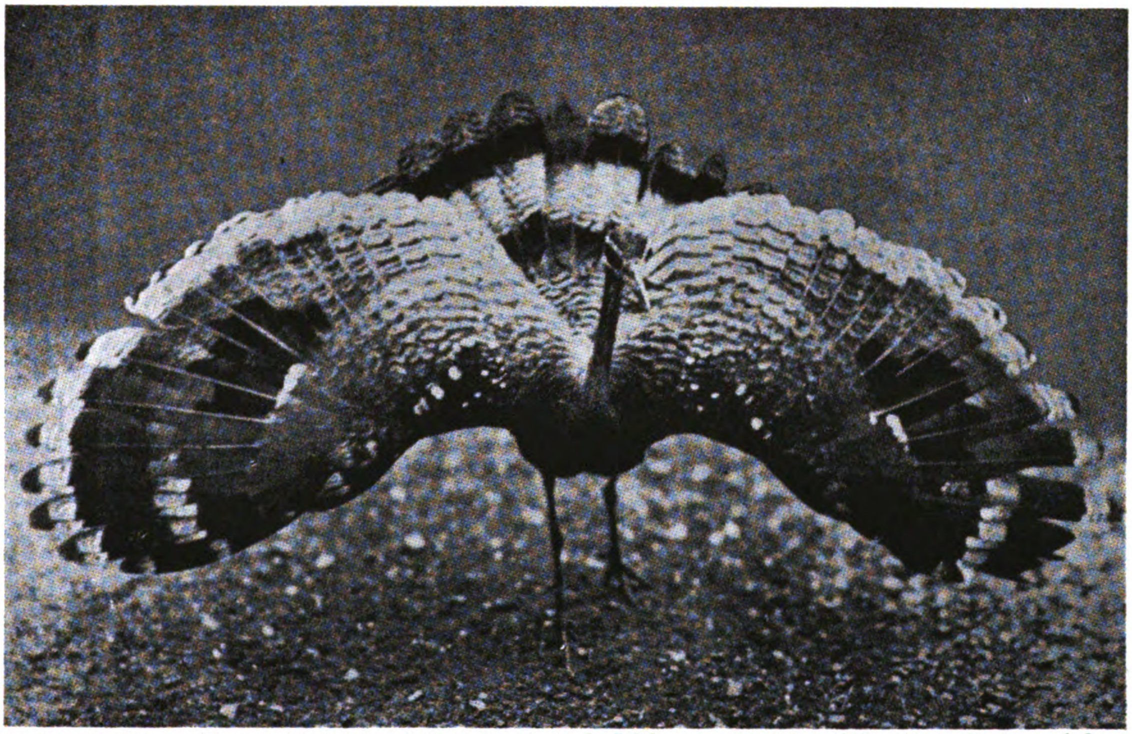
A colour-variety of the ordinary Peacock (*Pavo cristatus*), which hailed originally from India and Ceylon, but has been domesticated for a very long time. As in the ordinary Peacock, there is a wonderful display of the male's exuberant beauty at the courting season.

Photo: Neville Kingston.

PEACOCK DISPLAYING TO HEN.

The familiar tail of the Peacock, perhaps the most gorgeously exuberant of male decorations, is an exaggeration not of the tail-feathers in the ordinary sense, but of the tail-coverts. It is expanded in thrilling majesty in the eyes of the desired mate.

after the lyrics of the birds. There are howlings among monkeys and bellowings among deer. Fondling and kissing are well known, even among elephants. Occasionally there is a display of agility, as in the "March Hare." In some cases the males have special decorations which are shown off at the courting time, as when the Elephant Seal inflates the big hood above his snout. It may be that the fierce combats between rival males, as in stags, antelopes, and sea-lions, may sometimes serve to excite the females if they are spectators. But the victorious bully



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THE DISPLAY OF THE SUN-BITTERN (*Eurypyga helias*).

A shy river-bird, not nearly related to the Bittern. It spears its food, such as fishes and insects, by rapid thrusts of its bill. At rest and unexcited the bird is inconspicuous; when it spreads out its wings and tail at the courting season, it is an extraordinary display of colour.

does not give them much choice. On the whole, there is not much to boast of in the courtship of mammals.

Courtship among Reptiles and Amphibians.

One must not expect too much from cold-blooded animals, but a few of them have courting activities. The male crocodile curvets and capers in a most undignified way, roaring and bellowing at the same time, and perfuming the water with a secretion of musk from the skin glands of his lower jaw and tail. Pycraft, whose "Courtship of Animals" (1913) is a treasure-house and a biological education, once had the good fortune to see a Painted Terrapin flogging his desired mate's head with the whip-like ends of his long finger-nails. Some lizards show off their graceful frills and coloured collars, and one of their attractions is to open the mouth very wide to show the vividly coloured interior. This looks like wooing with a yawn! Some of the male newts indulge in amorous writhings and fondlings, as well as display; and we cannot listen to the croaking of the frogs in spring without being reminded that the first use of the voice was as a courting-call.

Courtship among Fishes.

In most fishes the sexes can hardly be said to meet, for the eggs are scattered in the water and fertilised more or less fortuitously. But there are cases where the rival males fight, where the male caresses the female, or swims around her excitedly, sometimes flushed with gorgeous colour as in the Gemmeous Dragonet. Yet there are fishes that strike a subtler note. In some ways the sticklebacks are most convincing

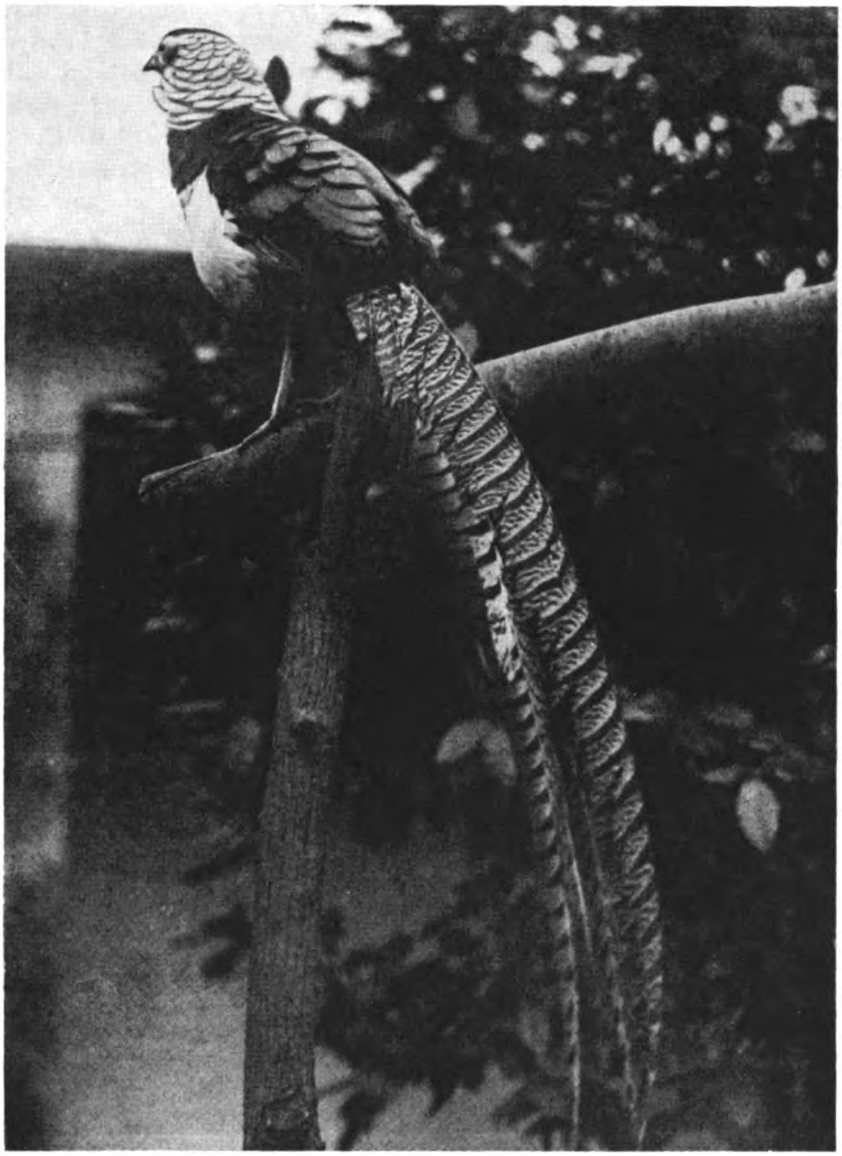


Photo: Reg. W. Stemson.

LADY AMHERST'S PHEASANT (*Phasianus* or *Thaumalia amherstiæ*).

This Chinese pheasant is nearly related to the Golden Pheasant (*Phasianus pictus* or *Thaumalia picta*), and is a very gorgeous bird with an extremely long tail. A third Chinese species is the Silver Pheasant (*Phasianus* or *Euplocamus nycthemerus*), a strong combative form, with a great deal of white in the upper parts and tail of the cock-bird.

of all. In another chapter we have seen how the male builds a nest and guards his family at the risk of his life. The excitement of the breeding season makes him very combative: he challenges rivals, trailing his coat, so to speak, for a fight. He is dazzling in his wedding robes of many colours. If a rival trespasses, there is a fierce fight. There seems to be a sense of property or possession in many of these low-grade creatures which throws a shield over nest and eggs and offspring. A remarkable feature in the stickleback courtship is the way the females behave when the males are jousting. They swim about in troops outside the battle-ground and now and then the victorious polygamous male selects a temporary mate from the company. But the females do not remain passive. "The female that heads the troop swims forward with rapid darts, followed by the others, suddenly stops, and assumes a vertical position with her head towards the bottom." The others follow suit and take up a similar position in the water. Then suddenly the leading lady deals a blow that scatters the crowd, only to re-form again in a few minutes around her or someone else. What does it all mean?

Quite a number of fishes make bubble-nests, and one of the best known is the Rainbow Fish, who is certainly an artist. The high-spirited male collects a few threads of fresh-water Alga and buoys them on the surface of the pool with bubbles of air squirted out of his mouth. He collects more filaments and blows more bubbles, so that a little floating island is formed. He makes this trim and compact, till it is like a green sunshade. Then there is the courting, and if the female does not approve of the sunshade there is a fierce quarrel. The male is quite in a passion. But when the course of love runs smoothly there

comes the time for embracing beneath the green sunshade. The eggs float up and are caught in the weed among the bubbles. In one species the eggs are heavy and sink to the bottom, but the male takes them one by one in his mouth and blows them into the bubble-nest. Another nicety in some species is that the bubbles have a thin film of oily material so that they do not burst so easily. In any case the male watches over the nest, keeping it in order, keeping it buoyant, replacing an egg if it falls out. When a young one ventures out too soon the father-fish blows it back again. He makes a veritable blow-pipe of his mouth. In an aquarium the end is apt to be rather tragic, for when the young ones are vigorous and move quickly in front of their parents, they are apt to be snapped at and devoured. For the parental instinct is all over for the time being, and a quickly moving object almost always pulls the trigger of a fish's snapping instinct. In natural conditions the young ones probably scatter before this "conflict of reactions" is provoked.

Courtship among the Lower Animals.

In the lower reaches of the Animal Kingdom there is often some sort of courtship, if we use the word to include signals between the sexes and the outward expression of sex-desire. In most cases this cruder courtship is so far away from our understanding that we get an impression of "queerness." Nature is sometimes *farouche*. The apparently apathetic snail shoots a beautifully formed arrow of lime at its neighbour, the *spiculum amoris* or Cupid's dart. Luminescent signals pass from the female Italian glow-worm or Luciola, sitting in the grass, to the even more luminous male who dances in the air, and the lady attracts a levée. The male deathwatch knocks his head against the wainscot; what is taken by the superstitious as a presage of death is his knocking at the door of his desired mate. The grasshoppers trill merrily, the cicadas "sing" to the breaking

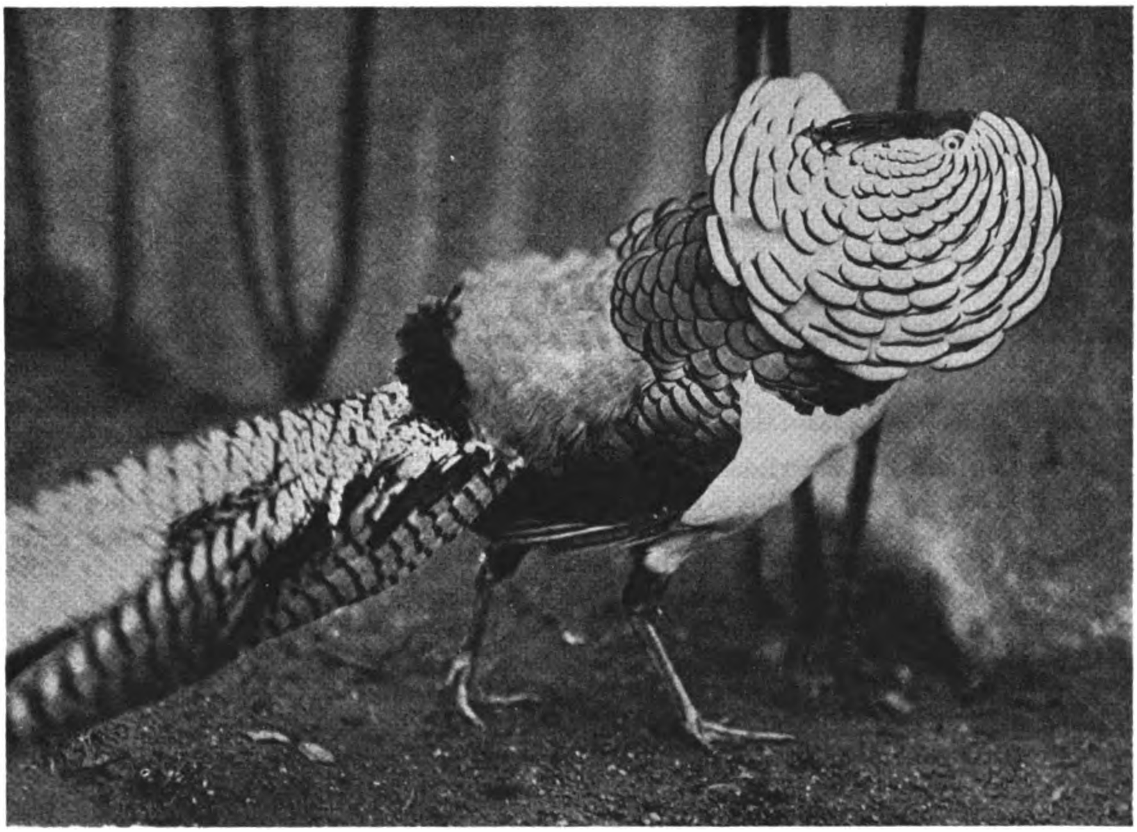


Photo: Neville Kingston.

LADY AMHERST'S PHEASANT (Phasianus or *Thaumalia amherstiæ*) DISPLAYING.

This Chinese pheasant, well known for the specially long tail and its brilliant plumage, affords fine illustration of display on the part of the male bird. He seems to take delight in parading his gorgeousness before the much less exuberantly coloured hen.

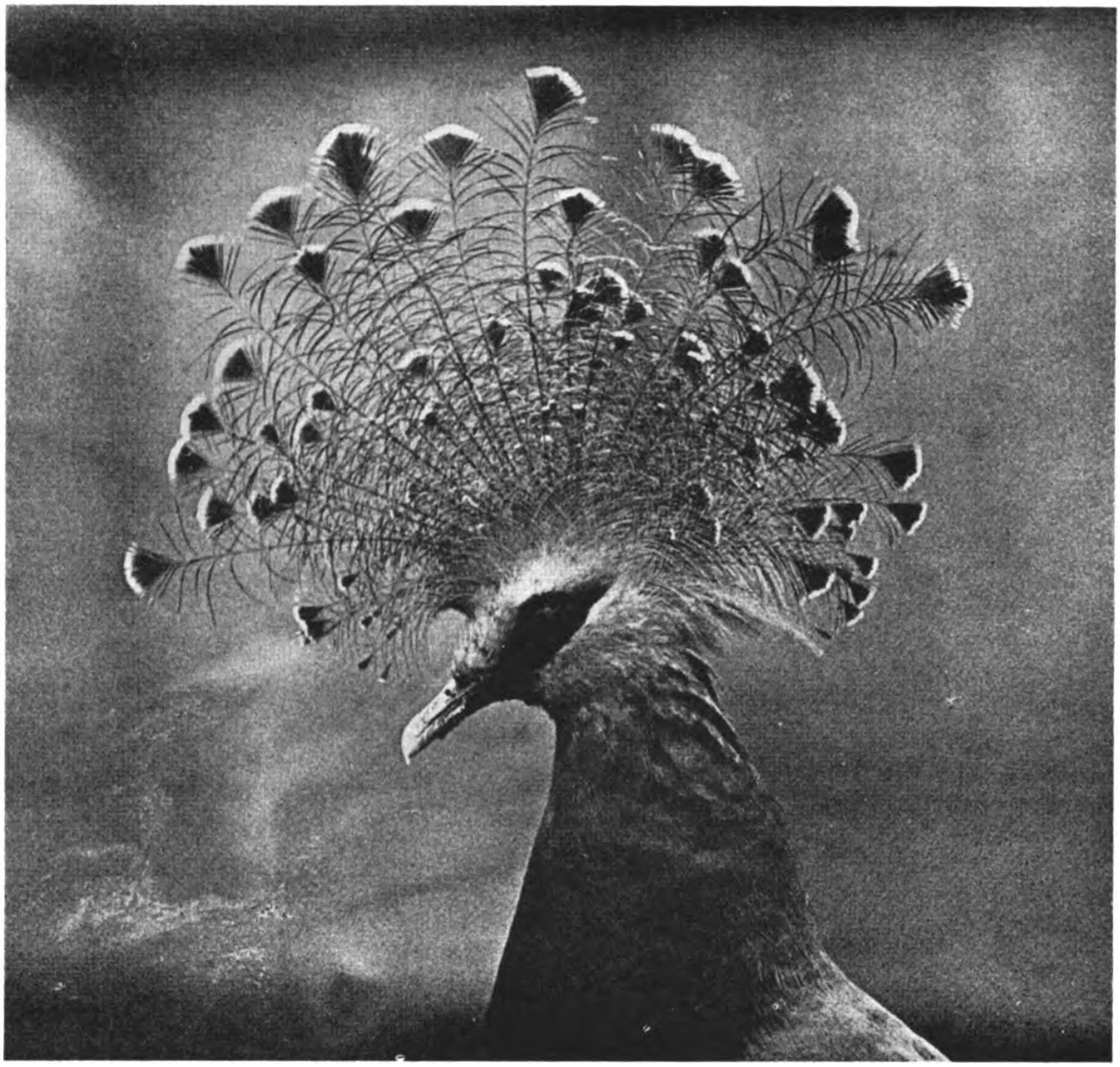


Photo: Neville Kingston.

THE CREST OF THE VICTORIA CROWNED PIGEON (*Goura coronata*).

A large and stately pigeon, of a lavender-grey-blue colour, with a chestnut mantle and a white wing-patch. It bears one of the most beautiful of crests, standing erect, with the individual feathers well spread out.

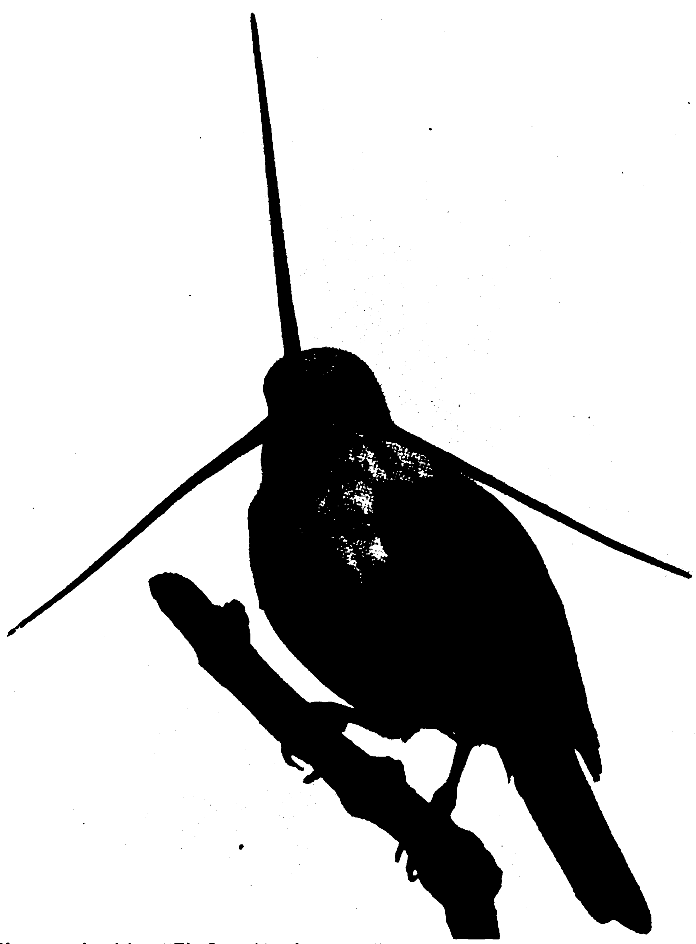
point to their voiceless wives (dull of hearing though they be), the crickets chirp, and there are other forms of instrumental music drawn into the service of "love" (please notice the inverted commas!). The male spider often fights with his rivals, lustily and skilfully, but not to much hurting; he dances round the capriciously tempered female, showing off his good points of colour and agility; he sometimes courts from a safe distance by vibrating a silken thread that leads to the spinster's web.

Very unusual is the audible signalling described by Dr. Karl Peters in the case of an Alpine moth (Endrosa or *Setina aurita*, variety ramosa), which he studied at Arolla. The males fly about actively, but the females are sluggish and rest for the most part on tussocks of grass, where they are very inconspicuous. It seems that the males are able to produce a crackling or snapping sound, to which the females respond by vibrating their body and wings. When the male flies overhead there is excitement on the female's part; she makes herself more conspicuous and exhibits tremulous movements. These seem to attract the male's attention. As very little is certain in regard to the sense of hearing in insects, this instance of audible signalling must be scrutinised critically. But the observa-

tions made by Peters are to the effect that when the male's sound stops there is a cessation of the female's movements. Even when the female could not see the male, she answered back when the sound began. Thus this seems to be a remarkable case, for the male's appeal is to the female's sense of hearing, while the female's answer-back is to the male's sense of sight. It would be interesting to have further observations. It may be mentioned that there are some cases among butterflies and moths of sound-production by rubbing one part of the body against the other, it may be wing against wing; and this is the well known "stridulation" or instrumental music of the fiddling grasshoppers, the monotonous katydids, the chirping crickets, and so on. But in the Alpine moth to which we have referred, the very distinctive note is due to the rapid vibrations of the margins of the anterior breathing apertures (or stigmata), and it is intensified by a special resonator! In many rapidly flying insects we have to distinguish the humming sound due to the rapid strokes of the wings from a special buzz due to the vibration of a membrane behind the breathing openings.

Another kind of appeal, also illustrated among butterflies, is by means of fragrance. Some male butterflies have a flower-like perfume associated with remarkable "plume scales" on the upper surface of the wings. A good example is the Green-veined White (*Ganoris napi*), and some of the relatives of the Common White are similarly fragrant. It is almost invariably in males that the special scent-organs occur, and it is practically certain that Fritz Müller was right in his suggestion that the pleasant flower-like scents are useful to the males in their courtship of the females, serving as extra means of attraction. An interesting point is the intricacy of the scent-organ in certain cases. There are scent-making glandular cells that secrete something in the nature of a volatile oil which steals off into the air; but there are also peculiarly modified scales, each with hair-like filaments, which serve to spread out the fragrant secretion so that it is more readily diffused. Quite different from the male fragrance is the odour of some female moths, especially when they have just emerged from the pupa state. The odour attracts the males if there is some breeze to diffuse it, and a number of males may be seen congregating even at a spot where a female was previously seated. But this is hardly to be ranked as courtship.

There is a moral to this story, for is it not one of the encouraging facts of Organic Evolution that fair flowers arise from earthy roots, more



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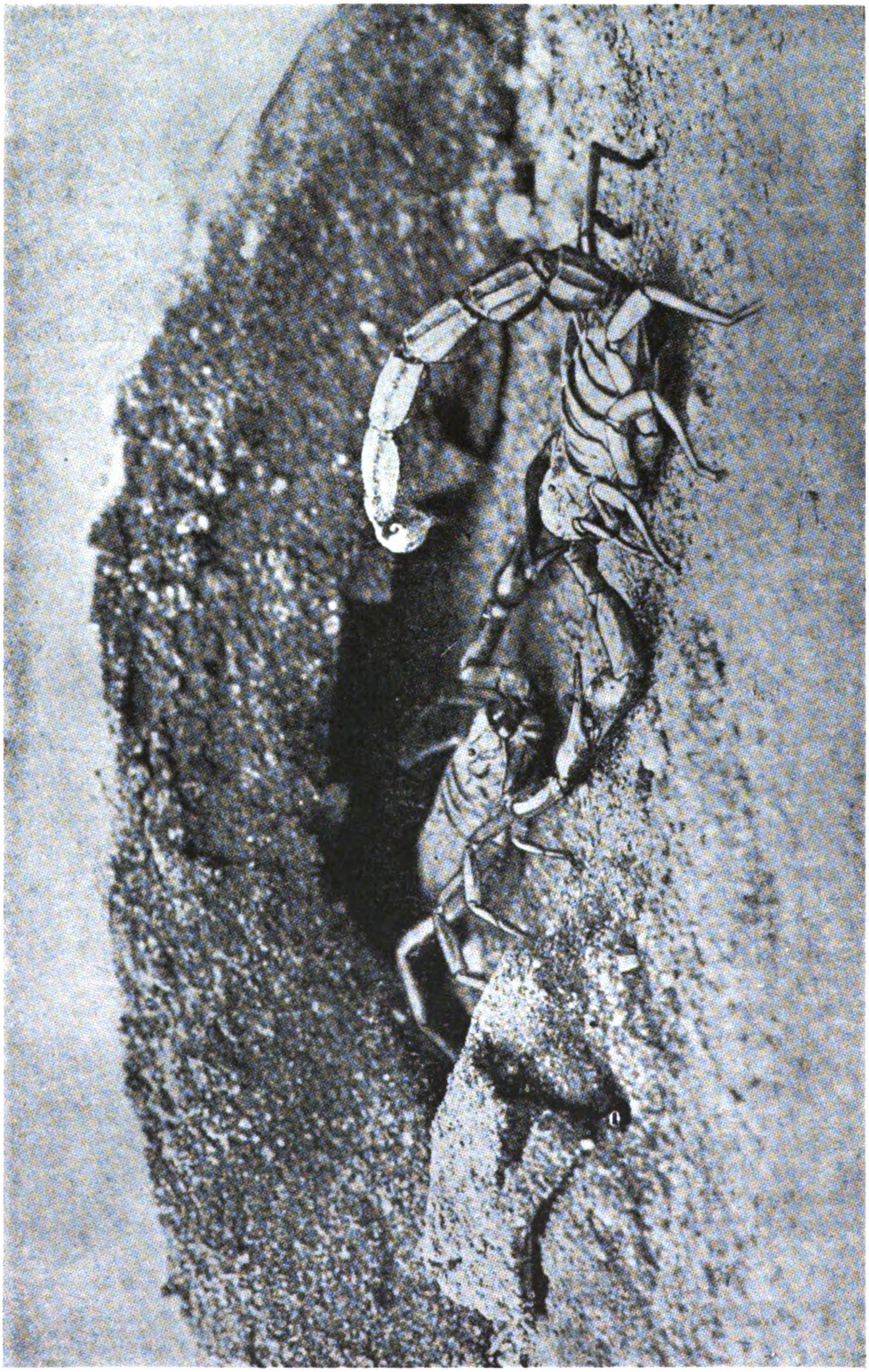
THE WHITE-HEADED BELL-BIRD (*Chasmorhynchus tricarunculatus*).

This is a Costa Rica bird, one of the Cotingidæ, the male of which bears at the breeding season three long erectile wattles, arising from the base of the bill, like the long pendants of a slipper-orchis (Cypripedium). The bird's note is loud and clear like the sound of a bell.



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THE COURTSHIP OF SCORPIONS.

With his pincers the male Scorpion seizes the pincers of the female and pulls her about in a curious way. The courting includes a "straight bend" of the supple segmented bodies, a prolonged nuptial stroll, and a final retreat into the male's resting-place. But often at the last moment the female changes her mind, escapes, and hurries away.

useful than beautiful? In the lower levels of animal life there is no wooing at all; imperceptibly there is an evolution of sensory appeals, and the lusty may become fond; gradually there appear indubitable expressions of emotion and hints of psychical as well as physical tenderness; the leaves of fondness become the flower of love, whence, may be, the fruits of the spirit. In any case, as Socrates said in speaking of the "religious and human love" of the halcyon, "there is comfort in this, both for men and women, in their relations with each other."

Photo: Chas. Barrett.

THE BEARDED DRAGON OR JEW LIZARD (*Amphibalurus barbatus*) EXCITED AND DISPLAYING THE WIDELY OPEN MOUTH.

In some lizards, such as the Frilled Lizard (Chlamydosdurus) the mouth is opened wide in moments of great excitement, and flushed with vivid red. In the Moustached Lizard (*Phrynocephalus mystaceus*) this happens when the animal is in a state of panic. In the Malayan Lizard (*Calotes emma*) the opening and shutting of the mouth is part of the courtship display.

Think once again of the extraordinary variety of courtship behaviour. As Brehm says: "The means by which a male bird declares his love and conducts his courtship are very various, but, naturally, they always correspond to his most prominent gifts. One bird woos with his song, another with his wings, this one with his bill and that with his foot; one displays all the magnificence of his plumage as a whole, another some special decoration, and a third some otherwise unused accomplishment. Serious birds indulge in play and jokes and pranks, silent ones chatter, quiet ones become restless, gentle ones combative, timid ones bold, cautious ones careless; in short, all show themselves in an unwonted light." Perhaps the unwontedness should not be so much emphasised, for what many birds exhibit in their courtship is but an intensification of what is seen in everyday life. But as to the variety and the abandon of the courting activities, there is no doubt. What does it all mean? That is to say, how has it been justified in the course of evolution? We seek to emphasise the answer that the more elaborate the courtship is, the more it tends to bind mate to mate by the cords of love. Part of the evolutionary justification of courtship is that the fitter males are more successful in pairing, and their descendants, inheriting their good qualities, will gradually

become the dominant types of the species. But another part of the evolutionary justification of elaborate courtship is that it makes or may make for a more successful mate-life or, to use human terms, married life.

Brehm speaks well, we think, of "the close fellowship so characteristic of bird-wedlock." There is often life-long monogamy. Pairs of booted eagles were easily recognisable as mates even when they travelled or took shelter in company with others of their species. The whistling swans which I saw on the Menzaleh Lake in Egypt appeared in pairs and flew away again in pairs; all the other united pairs which I observed on my journey illustrated the same habit. That they share misfortunes as well as pleasures, I learned from a pair of storks I observed on a pool in South Nubia, to whom my attention was attracted because they were there at a time long after all others of their species had sought a refuge in the interior of Africa. I found that the female had a broken wing which prevented her travelling farther, and that the male, himself thoroughly sound, had remained, for love of her, in a region where all the conditions of comfortable wintering were absent. The close and faithful bond between monogamously mating birds is severed only by death.

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YOUNG ELEPHANT SEAL (Macrorhinus).

This striking photograph of the young Elephant Seal shows the large eyes, the sensitive hairs, and a head not very different from that of ordinary seals. In the adult male, however, there is a very remarkable inflatable snout, which is relaxed and pendent when the animal is unexcited, closely contracted during combat, and greatly expanded during courtship.

Strange Cases.

There are some exceptional cases which are as interesting as they are difficult to understand. Thus among the Hemipods or Bustard-quails, small quail-like birds which inhabit Africa, India, China, Burma, Malay, and Australia, the females are in many cases larger and more decorative than the males. In what are regarded as the more old-fashioned species, the sexes are alike; so it looks as if the females had diverged in the direction of handsomer plumage. "The male is a very plain-plumaged little fellow, but the female towers above him in size, and has often a black throat or a rufous collar as a distinguishing character." In species where the females are the larger and handsomer, only the females call and fight. The males brood on the eggs, while the females roam about, "calling and fighting, without any care for their obedient mates; the males and the males only, tend the young, and are to be flushed along with the brood." "After having deposited her three or four eggs in an apology for a nest, the female leaves the incubation and rearing of the young to be performed by her husband, weak little man that he is, while she roams about, seeking for some equally strong-minded lady to fight with."

The same sort of reversal of the usual state of affairs is seen among the Phalaropes, graceful birds of the North. Let us take the case of the Red-necked Phalarope (*Phalaropus lobatus*), an attractive summer visitor to some parts of the Orkneys, Shetlands, and Hebrides, and to one

Specially drawn for this work by Roland Green, F.Z.S.

COURTING OF THE BUBBLE-FISH (*Macropodus viridi-auratus*).

The male sucks bubbles of air into his thick-lipped mouth and drives them out again coated with a little salivary secretion. They cohere in the water and serve to buoy up some pieces of freshwater Alga, which form the floating bubble-nest.

district in Ireland. It is about seven and a half inches in length, looking half the size of a dabchick when swimming. It shows great liveliness on the water and indifference to man's presence. The colour scheme in summer is a mingling of slate-grey, fox-red, and white. Now the female is a perfect female, but she is very masculine in several ways; she courts and she fights, and she is more richly coloured than her mate. The male is a perfect male, but very feminine in many of his ways; he does most, if not all, of the brooding, and looks after the young ones, which have golden down to start with. Sometimes the hen mounts guard near the nest and warns the cock to slip off when danger is imminent.

We quote Mr. E. W. Nelson's account of the behaviour of these interesting birds. "The dull-coloured male moves about the pool apparently heedless of the surrounding females. Such stoical indifference usually appears too much for the feelings of some of the fair ones to bear. A female coyly glides close to him, and bows her head in pretty submissiveness, but he turns away, pecks at a bit of food, and moves off; she follows, and he quickens his speed, but in vain; he is her choice, and she proudly arches her neck, and in many circles passes and repasses close before the harassed bachelor. He turns his breast first to one side, then to the other, as though to escape, but there is his gentle wooer ever pressing her suit before him. Frequently he takes to flight to another part of the pond, all to no purpose. If, with affected indifference, he tries to feed, she swims along side by side, almost touching him, and at intervals rises on wing above him, and, poised a foot or two over his back, makes a half-dozen quick, sharp wing-strokes, producing a series of sharp, whistling noises in rapid succession. In the course of time, it is said, water will wear the hardest rock, and it is certain that time and opportunity have their full effect upon the male Phalarope, and soon all are comfortably married. The captive male is introduced to new duties, and spends half his time on the eggs, while the female keeps about the pool close by."

This is a very striking case. Four or five females will sometimes worry one male. Rival females sometimes fight with one another, just as rival males so often do. A quaint observation is to the effect that the male is not always keen to take on the task of brooding, and that his mate sometimes bullies or "henpecks" him into obedience. It would be very interesting to make a careful physiological examination of the two sexes of Phalarope, to see if there is any unusual contrast in the sex-hormones or any marked difference in the time at which the males and females become quite grown-up or "marriage-ripe."

LXVI
ANIMALS AND MAN

THE circle of man's life cuts into that of many animals, such as those which he uses for food or in domesticated partnership. We wish to give a variety of instances of these inter-relations. But the circle of many an animal's life intersects man's, sometimes as an enemy and sometimes as a dependent and sometimes as a parasite. This also deserves illustration, necessarily very diversified.

The Oyster.

Very characteristic of the shallow water near shore is the oyster—not an animal of many "habits," yet of great interest. We might have given it a place among our "shore-animals" in this book, but we have taken it here because of its long-standing, indeed prehistoric, gustatory interest to man.

When the month has not an "r" in its name then we may eat oysters, and an enthusiast has written of

> "those four sad months wherein is mute that
> one mysterious letter that has power to call
> the oyster from the vasty deep."

In other words the oyster is "in season" from September to April, though the impatience of the

palate has often led to spelling August with an "r." The meaning of being "in season" is simply that the oysters have recovered their condition after the exhaustion of spawning, which usually occurs from May to July. According to the ancients the full moon brings the oysters into good condition: *Luna alit ostreas*. This is not a foolish idea, but modern biologists put in a big mark of interrogation here.

When we allow the "native" to glide past our taste-buds—"that flash of gustatory summer lightning," as Huxley called it—we are not usually in a mood for scientific reflections. All we want is to enter into intimate but non-intellectual relations with a hors d'œuvres stimulant of a subtle pleasant taste and of very rapid digestibility, which prepares the way for more serious food. The oyster pulls the trigger of digestion; thus, when it is accompanied by a sprinkling of lemon, it evokes a "chemical messenger" or hormone which serves as a key to open the lock of the sweetbread or pancreas—the most potent of our digestive glands. Besides all that, the succulent mollusc produces a feeling of general pleasedness which helps us to make the most of our meal. We can understand, then, why there are not many edible animals that have been so enthusiastically described as the oyster, especially by the Romans, who, by the way, had the good sense and the bad manners to chew the delectable morsel. Sallust, we believe, condescended to overlook the defects of our ancestors, the "poor Britons," because of the fine oysters they produced, and this left-handed compliment was worth having from a countryman of the critic who

"could tell
At the first mouthful, if his oysters fed
On the Rutupian or the Lucrine bed
Or at Cerceii."

Perhaps we do not think enough of the prehistoric discovery of the oysters. The trend of anthropology is to show that prehistoric man was not the condensed menagerie that used to be supposed, but a kindly, sociable fellow, full of inventiveness and fond of art. No modern inventor like Edison can be compared for a moment to our unknown ancestor who first made a fire or a wheel, an alphabet or a boat. And besides these big things we must remember with gratitude the ages during which prehistoric men pursued, in regard to plants and animals, the scientific procedure known as the "trial and error" method. If he ate couch-grass he had severe pains; if he ate the wild wheat of Mount Hermon he had the content of a good meal; if he tried the carrot or the earth-nut he found satisfaction, but when he tried another member of the same natural order Umbelliferae, namely, the hemlock, why, he came to a full-stop. Similarly when he tried the dog-whelk or the false-oyster (Anomia) he knew the repentance which George Eliot speaks of as "the weight of undigested meals ate yesterday"; whereas if he ventured on the winkle and the true oyster he dined. We are not grateful enough to our remote ancestor for starting a physiological "black list" and for discovering such delicacies as the oyster.

It is not, to look at, a very prepossessing animal, and it is almost the only one except the cheese-mite that we voluntarily eat alive. As King James was wont to say, "He was a very valiant man who first ventured on eating of oysters." The same sentiment is expressed by the poet Gay:

"That man had sure a palate covered o'er
With brass or steel that on the rocky shore
First broke the oozy oyster's pearly coat,
And risked the living morsel down his throat."

But what of the irrelevant scientific reflections on eating an oyster? One is that we are enjoying the end of a very remarkable life-history! The parent oyster, unlike the periwinkle, or "poor man's oyster," is male and female in one, sometimes in alternate years, and it is extraordinarily prolific. It produces so many eggs, that it is very difficult to count them conscientiously, and the estimates vary from 300,000 to sixty millions, the figures showing that naturalists, like Nature, sometimes work with a big margin. But a six-year-old female oyster may be safely credited with a million eggs, and more of course in the American species. "How fertile be the floods in generation," as Spenser says in his "Faery Queen."

The microscopic fertilised eggs of the oyster accumulate about the gills and mantle-folds, and the animal is said to be "white-sick." In about a fortnight they have developed into greyish or bluish ciliated larvæ, and then the oyster is said

to be "black-sick." The mollusc opens the valves of the shell and ejects its offspring or "spat" in living jets. The minute creatures then enjoy a period of free-swimming, but this cannot be extended beyond forty-eight hours. The first big chance against success in life is that the spat be washed away to quite unsuitable places, where it could not settle and where oysters could not grow. A second chance against them is that they may be speedily swallowed by the hungry creatures, such as other bivalves, worms, small crustaceans, and young fishes, that feed on the microscopic stock of the sea-soup. A third mischance would be a spell of cold weather, for the spat will not "fix" if the temperature of the water is not fairly genial. We mention these chances of death because they show that non-prolific oysters could not have survived in the struggle for existence. The succulent delicacy that we enjoy is elect among millions. "How careful of the type she seems, how careless of the single life." It has been calculated that out of a million eggs only one becomes even a half-sized oyster.

If the larva is lucky and sinks in relatively shallow water on to a suitable substratum, such as one with clean and empty oyster shells, it fixes itself, loses its locomotor lashes or cilia, and begins to grow rapidly. In six months it has increased from a twentieth of an inch in diameter to the size of a threepenny bit. In a year it has attained the size of a shilling or half-a-crown; and it goes on growing at the rate of about an inch every year for perhaps ten years. It is at its prime at five years, and if we swallow the elect at that age we may console ourselves with the reflection that they have had two or three opportunities to replace themselves in the sea. It may be mentioned that the rings of growth, which we see on the outside of the shell, are not *annual* marks, for several are made in the course of a season.

But the young oyster's troubles are by no means over when it settles down. It is too palatable to be free from enemies. Crabs and octopuses break the small shells; skates devour large ones; many of the carnivorous sea-snails, like the dog-whelks and buckies, get at the delicate flesh, perforating the shell by means of an acid secretion and the flexible file which they all carry in their mouth. These perforations are not to be confused with those due to a minute boring sponge called Cliona, whose disintegrating work we often see on oyster shells thrown up on

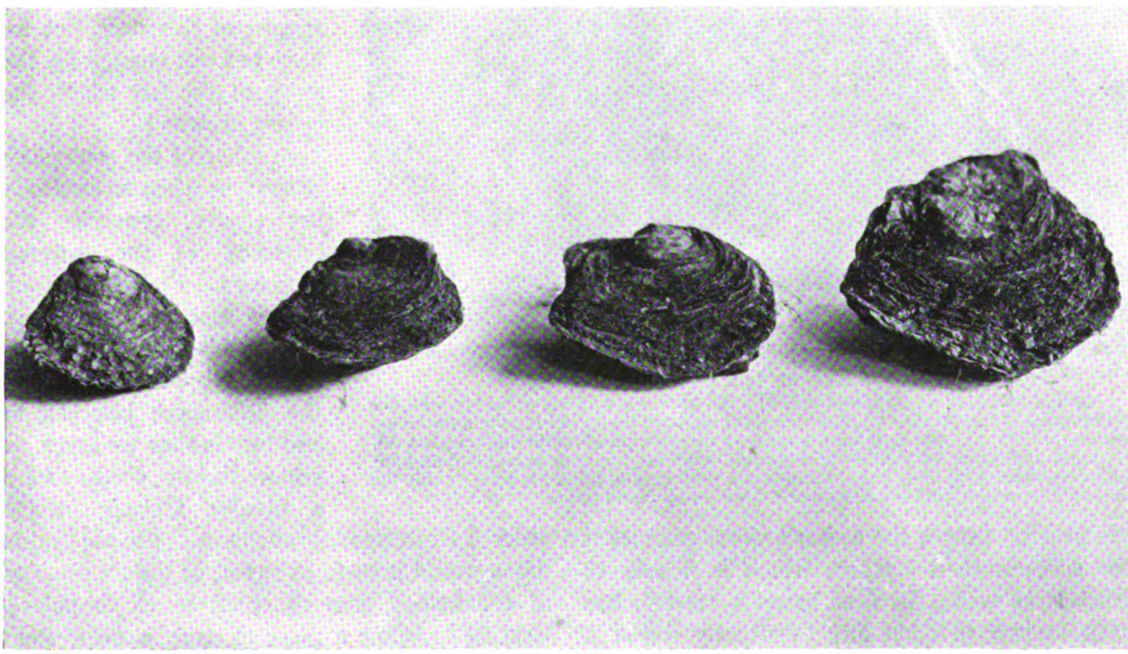
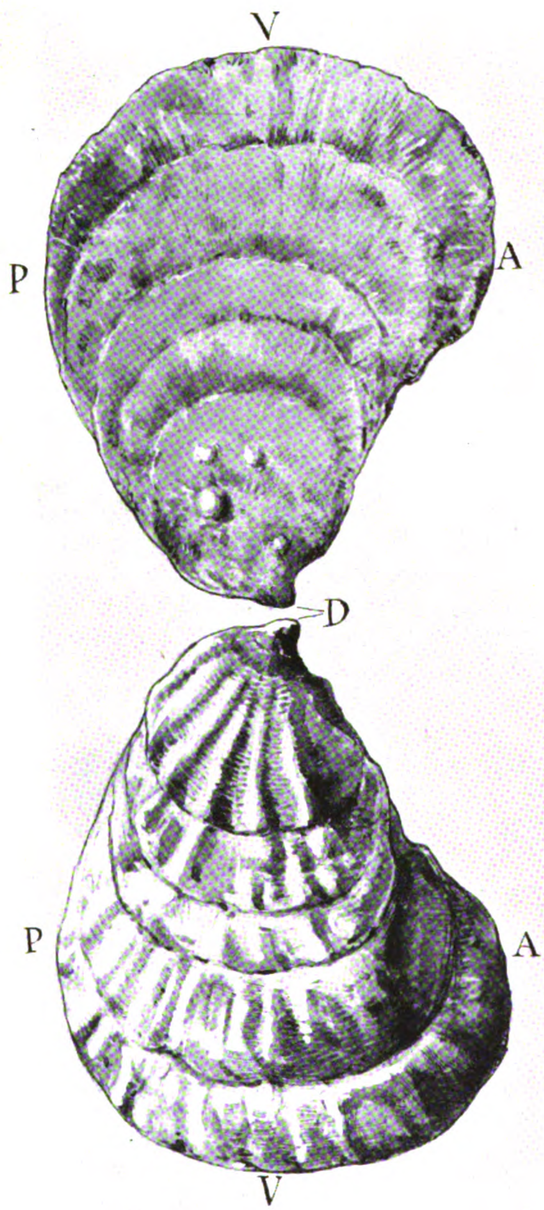


Photo: Sport and General Press Agency.

GROWTH OF THE OYSTER.

The four shells, from left to right, are three months, six months, one year, and two years old. When a year old the shell is often about an inch across on its longest diameter; and it is often said that an oyster is as many years old as it is inches across. An oyster is at its best when about five years old.



SHELL OF THE OYSTER.

The lower figure shows the convex outside of the left valve, the lower one in life, with five distinct zones of growth. The straighter margin of the valve is posterior (P), the more curved margin is anterior (A). The hinge line is dorsal (D): the gaping margin of the shell is ventral (V). The upper figure shows the flat outside of the right valve, the upper one in life, with the same zones of growth. A big zone often corresponds to a year's growth, but this is not necessarily the case, for several big zones are sometimes laid down during a good year.

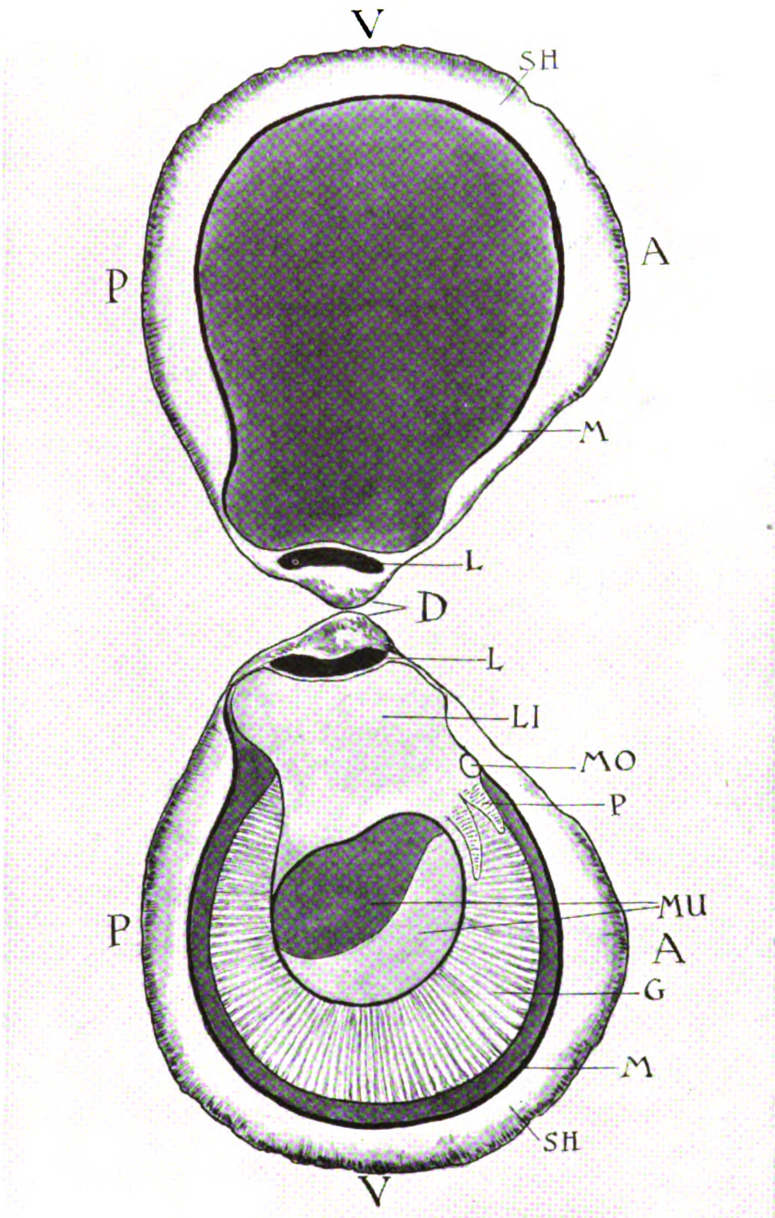
the beach. One of the oyster's worst enemies is the soft-mouthed starfish, which is deadly to mussels as well. In four hours a starfish has been known to open and eventually digest a small oyster the size of a shilling. The starfish protrudes its very elastic stomach and partly envelops the oyster; it thus manages to introduce a toxic juice which paralyses the closing muscle so that the valves must gape. Then all is easy. Another and frequently recurrent risk in the oyster's life is that of being smothered by extraneous growths on the shell and by shifting débris. Throughout its life, then, the oyster is being sifted, and those we enjoy represent the result of the final winnowing of the fisherman's dredge. Meanwhile, happily, there has been profuse sowing to balance the severe sifting.

One is not sorry to hear that the oyster sometimes turns the tables on an incautious molester by rapidly closing its gaping valves. Exposed oysters have been known to shut their trap on biggish animals that had taken to hunting at very low tide. Rats have been caught in this way, but we have not salt enough for the story of the fox which the oyster drowned.

Another of the zoologist's reflections when he swallows his oyster concerns the intricacy of the internal structure. Prehistoric man was as fond of them as we are, as his huge "kitchen-middens" prove, but one of the differences between us and him is that we know we are swallowing *Ostrea edulis*, a bivalve mollusc in the order Pseudolamellibranchiata. By any other name would it taste as sweet, or does a soupçon of conchology give the final touch to palate-tickling? What a piece of work is an oyster! It has neither head nor foot, but it has many intricate organs such as heart and liver, kidneys and gills, a central substantial muscle for closing

the valves, and around all a fold of skin called the "mantle" which secretes the shell, adding to it periodically, line upon line, layer upon layer of carbonate of lime and an organic matrix called conchin. The gills, which form the oyster's "beard," are attached to the mantle, and consist of a multitude of filaments covered with beating cilia. If a little piece be cut off, it will swim away; and we cannot wonder at the enthusiasm of Leeuwenhoek, one of the greatest of the early microscopists. "The motion I saw in the small component parts was so incredibly great that I could not be satisfied with the spectacle." The lashes on the gills serve to keep up a current of water for breathing purposes, but they also waft microscopic food-organisms to the mouth.

The oyster is a very dainty feeder, depending mainly on microscopic plants known as diatoms, and on microscopic animals known as Infusorians. If less innocent organisms or injurious particles get past the sieve of the ciliated gills, they tend to be rejected by the fastidious lips which surround the oyster's mouth. The much-prized "green" oysters of Marennes owe their colour to a particular bluish diatom on which the oysters feed in the fattening ponds or "claires"; and it may be noticed that oysters dredged from muddy waters can be readily made quite clean by keeping them for some days in a wholesome current.



AN OPENED OYSTER (Ostrea).

The lower valve is the left, turned downwards and often fixed in the living animal. It is saucer-like, whereas the right valve, turned upwards in the living animal, is very flat. As the right valve is much lighter than the left, it is by lifting it that the oyster opens its shell. The following structures are shown on the animal lying in the left valve: M, the mantle or skin-flap, lining the shell and making the shell; G, one of the four ciliated gill-plates, a pair on each side; MU, the closing muscle which draws the two valves forcibly together; P, the ciliated palps or lips wafting microscopic food-particles into the mouth (MO). Above the closing muscle is a region occupied by the stomach, the liver, the heart and the reproductive organs. As the oyster is a sedentary bivalve, the muscular "foot," usually strong in these animals, is undeveloped. In the hinge near the oldest part of the shell, there is an elastic pad or ligament (L) of conchin, which helps the raising of the right valve. In the upper valve, thrown open as it were, the right half of the mantle (M) is seen lining the shell, to the size of which it is always adding. A is anterior, P posterior, D dorsal, V ventral.

Though Shakespeare indirectly confirms the common saying, "as stupid as an oyster," its point seems to us somewhat blunt. There is no stupidity in the way the oyster shuts its valves

when the shadow of the dredging boat activates the sensory spots on the margin of the mantle. There is no stupidity in the way they can be educated to keep their shells shut for a longer and longer time when out of water. The oyster-farmers gradually increase the period during which they leave the oysters exposed, and the oysters learn to retain a quota of water by keeping the shell-closing muscle firmly contracted. They used to open their valves on the journey from Normandy to Paris; now they keep them shut all the way! That is very far from saving the oysters, for it makes them more desirable than ever, but no one can call it "stupid." We cannot leave oysters without speaking of oyster-culture, and without regretting that there is not more of it in Britain, which long ago furnished the Romans with some of their best stocks. It is a pity that oysters are not more abundant, for they form a very valuable commodity, and the creatures are like bees in not requiring to be fed. The main reason why oyster-culture is not more widespread is that it requires, as we shall see, a combination of happy circumstances if it is to be a success.

Oyster-culture.

Oyster-culture has been practised in Britain for many centuries—Whitstables were famous in the time of Agrippa (A.D. 78)—but, so far as we know, it has never passed from culture to selective breeding. When oysters from one country are bedded out on the shores of another—as the Romans took those of Richborough in Kent, to stock their Rutupian beds—that is still culture and nothing more. What man has mostly done has been to collect the settled larvæ or "spat" and place them in conveniently situated natural or artificial shallows—the "park"—where they may be sheltered from many of their enemies and find abundant food whereon to grow and wax fat. For fat oysters are favourites. When there is a good "spatting" year, which is not very often, arrangements are made to secure for the larvæ suitable surfaces—such as tiles and twigs and empty shells—on which to settle down. This may be within the precincts of the oyster "park"; or the shells and tiles with adherent young oysters may be shifted from more open waters into shelter. The difficulty is to find a suitable site for the parks. As Huxley tersely puts it, "They must be protected from storms, and yet have free access to the sea; shallow, and yet not liable to become too hot in summer or too cold in winter; open to currents which bring nutriment, and yet not liable to be silted up by mud." There is bound to be difficulty in fulfilling all these conditions; yet most of the successful British oyster-beds are artificial. Transplantation of young oysters from natural beds to artificial beds is very common and very profitable.

The advantages of the artificial park are manifold: the oysters can be more readily lifted when wanted, without tearing up the beds with a dredge; they can be sheltered (more or less) from such enemies as dog-whelks, tingle-whelks, and starfishes; they can be kept free from smothering growths and impurities in the water; and they can be supplied with abundance of suitable natural food. It has been mentioned that all oysters feed daintily on microscopic organisms. Those that give trouble to normally constituted consumers have ceased to be fresh and have developed ptomaines; or are "out of season," i.e., laden with eggs or sperms; or have sojourned in water that contained dangerous microbes. But oysters are as safe as most things.

It is astonishing at first sight that oysters should ever be scarce and dear, for the animal is so prolific. Professor W. K. Brooks, a distinguished American zoologist, computed that an average Maryland oyster lays about sixteen million eggs, and that if half of these were to develop into female oysters which also laid eggs there would be in the second generation eight million times eight million oysters. In the fifth generation, if all went well, there would be enough of oysters to make a mass eight times the size of the earth, allowing eight cubic inches to each oyster. There would be sixty-six with thirty-three noughts after it. It is hardly possible that our European oyster could ever produce quite so many eggs as the American one, but it has the advantage of keeping the eggs within its shell until after they are fertilised and have developed into larvæ.

But there is no doubt that our British oysters are *very* prolific, and it is probably safe to credit a five-year-old Whitstable oyster with producing about a million eggs when it is in a female state.

If we swallowed it in the September of its fifth year, what should we be doing from a biological point of view? (*a*) We should be destroying the possibility of millions of oyster spat in years to come, for an oyster may survive for ten years or more, even in a world unfriendly to such palatability. (*b*) We should be swallowing the elect out of a million, for that is the percentage of survival calculated by Professor Moebius for an oyster that has attained half-size—and five inches is more than that. (*c*) But we should be destroying, and this is our biological excuse, an organism that had been allowed three or four annual opportunities of replacing itself in the sea. The general fact stands out clearly: there is a prodigious birth-rate, but there is terrific infantile and juvenile mortality. And it is this mortality that oyster-culture lessens.

The practical problem is: How are we to get more oysters? It has been suggested that we

Photo: Exclusive News Agency.

OYSTER WORKERS IN THE BASSIN D'ARCACHON.

Oysters brought in from a natural bed may be "fattened" in a conveniently constructed seashore pond; "fallen spat," that is to say newly fixed young oysters, may be brought from elsewhere to sheltered or otherwise favourable culture-grounds; or oysters may be reared from first to last in suitable places where abundance of food is secured and enemies like starfish are weeded out.

Photo: Exclusive News Agency.

AMBULANCE CASES FOR YOUNG OYSTERS.

In dredging oysters from their natural beds at depths of three to twenty fathoms, there is often a considerable breakage of shells, and one of the economical devices at Arcachon and elsewhere is to nurse these accidentally crushed specimens until the shells are mended and marketable.

should eat fewer, which is absurd, as Euclid used to say. Everyone knows that in these affairs the greater the demand, the greater will be the supply. If more people wished for more oysters, there would soon be more. It has also been suggested that more care should be taken of the natural beds, so that over-dredging is avoided. This has been in some cases attempted by means of "close times," "minimum sizes," "protective measures," and so on; and of course everyone is in favour of taking all reasonable care of natural resources. But the difficulty is that, in spite of regulations often as stringent as is practicable, the natural beds tend to dwindle. It is not easy for man to protect animals in their natural environment. The sure line is more oyster-culture and still more oyster-culture.

No doubt the fishermen of all times have had intimate knowledge of some of the habits of the fishes they caught; necessity gave an edge to their Natural History. But the definite application of science to the conservation and improvement of fisheries—large and small—is very recent, and must be cautiously illustrated.

Fisheries.

(*a*) The elementary fact that the developing eggs of almost all the marine food-fishes float near the surface was till recently ignored or denied by practical fishermen; but it is of great importance since it shows that trawling along the floor of the sea cannot directly injure the eggs and early stages. The only exceptions of importance in Britain are the herring and the skate, and their near relatives. (*b*) The established fact that some fishes have spawning-grounds in one part of the sea and feeding-grounds in some other part, as in the case of plaice, suggests the plan of transplanting millions of young fry from the crowded nurseries to grounds suitable for growth, though not for spawning. Thus there may be a peopling or re-peopling of relatively empty areas. (*c*) Whatever practical excuse there may be for "over-fishing," there seems to be no escape from the conclusion that limited areas, such as the North Sea, have begun to suffer from the intensive use of methods which are in certain aspects wasteful. From the Natural History point of view it is extremely short-sighted to catch fishes before they have had an opportunity of replacing themselves by spawning. In weeding on land, where the end desired is elimination, it is important to remove the weeds *before* they seed. But the more this is done in fishing, the more is the persistence of

an abundant supply endangered. Thus it is in the long run very unprofitable to catch haddocks before they are two years old, or, let us say, before they are six inches long, for these immature haddocks have not replaced themselves. In natural conditions there is, of course, stringent and continuous sifting, but the chances of death are reduced with increasing age and a balance is reached in Nature between numbers and risks. But when man intervenes and secures big catches of fishes that have survived the severe natural sifting during early life, and yet have not spawned, the result must be an upsetting of the balance. When haddocks are caught *after* their first spawning, there has been an automatic counterbalancing of the numbers removed by fishing, until, at least, a limit is reached when the intensity of capture far exceeds the possibilities of replacement. The problems are difficult, and there is much difference of opinion in regard to details, but there is all-round agreement on two points: that the regulative control of fisheries must be based on secure Natural History data; and that the shrewdest measures are those which increase the chances of marketable fishes reaching their best growing period and, at the same time, spawning age. (*d*) On a small scale it has been proved that the number and average size of trout in a freshwater loch may be increased by tumbling in cartloads of bracken and similar material. The bracken is decomposed by bacteria; these and some of the results of their activity afford sustenance to infusorians; these feed small crustaceans, which in turn are reincarnated in trout. This kind of intervention depends on an understanding of the linkages or inter-relations in Nature, and it is probable that similar methods may have to be utilised to counteract the effects of over-fishing in limited

Photo: Exclusive News Agency.

DREDGING OYSTERS: NEW JERSEY.

Oysters usually live together in large numbers on banks that are suitable for the fixing of the young spat and also afford abundance of suitable débris of seaweed, sea-grass and the like. They flourish at depths of three to twenty fathoms, and are in most cases collected by means of a dredge—a somewhat wasteful method. But young oysters are often cultivated in shallow artificial beds, from which they can be gathered by hand or by using rakes and tongs.

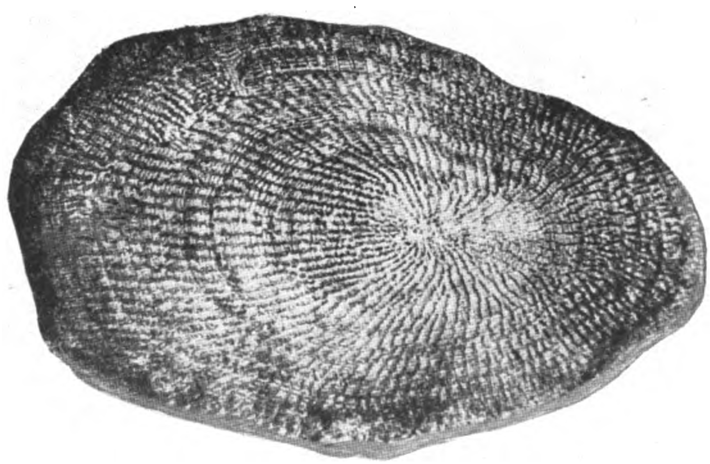
areas in the sea. Mackerel feed mainly on swarms of copepod crustaceans, which depend on the myriads of diatoms and Peridinid Infusorians living near the surface of the sea, whose rate of multiplication is correlated with the amount of sunshine. It is on a recognition of this complexity of linkage that control of fisheries must be based if it is to be successful.

The Haddock.

In North Europe the three most important food-fishes are the plaice, the herring, and the haddock. If it be asked why not emphasise the great halibut, for instance, the answer is that this fish does not spawn in the North Sea; and, moreover, the halibut does not show the influence of man's interference to anything like the same extent as the plaice. If it be asked why not emphasise the lemon sole, for instance, the answer is that its relative the plaice is much more of a favourite, and grows to be a much bigger and plumper fish. Or if it be asked why we should think more of the haddock than of the whiting, the answer must be that the haddock is much more abundant, that its average size is larger, and that its flesh is firmer and suited for curing. We believe that nearly half of the immense total weight of fish caught every year in the North Sea is made up of haddocks. Their value may exceed £3,000,000 in one year.

The haddock is a good average representative of the cod genus (Gadus), and its chief distribution is in northern waters. It differs from its relatives in a crowd of rather trivial features which we call species-characters. Thus in front of the lower jaw of a cod there is an inch-long barbule, believed to be tactile; but there is only a vestige of this in the haddock, and it is absent altogether in the whiting. It may be said at once that size does not count for anything in distinguishing fishes, since most of them grow and grow without that limit of growth that punctuates most animals. One reason for this is simply that the weight of the growing body is supported by the water.

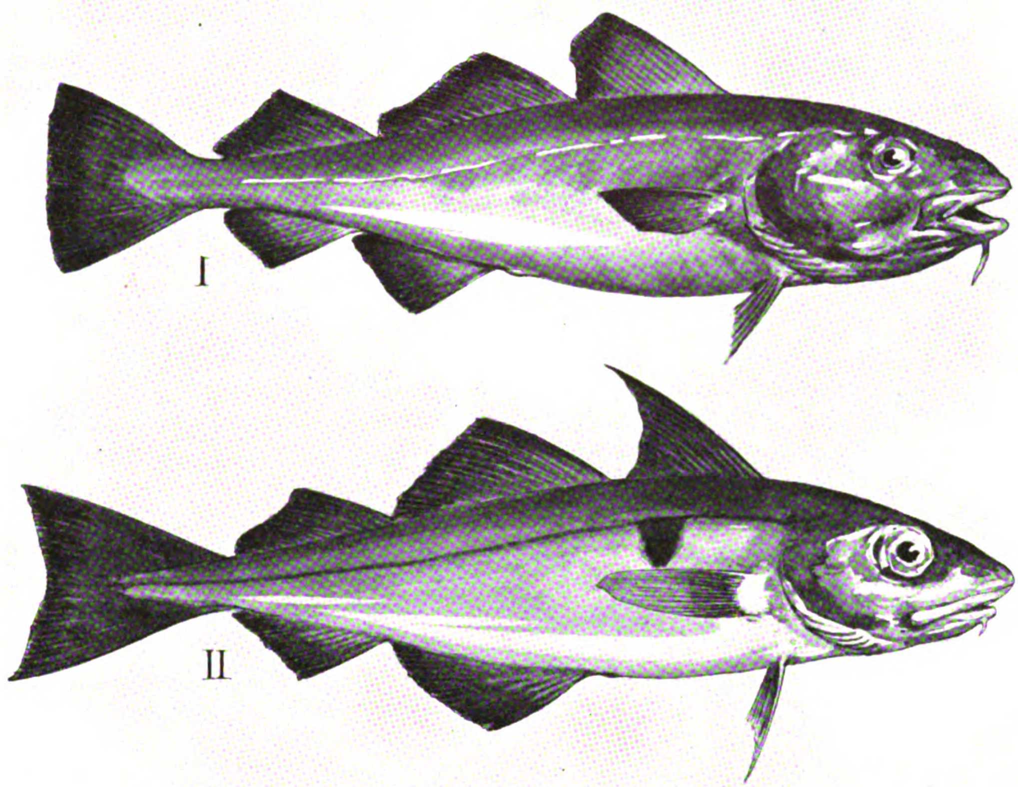
Although a haddock may grow to be nearly a yard long, it grows at different rates at different times of year—very little in winter; and as this is registered on the growth-rings of the scales it is readily possible to tell a haddock's age, just as we can tell the age of a tree by counting the rings on the sawn surface of its stem. The haddock, like other Gadoids, is one of those fishes where reading the age from the scale-rings is quite secure and relatively easy. The same is true of the salmon, whereas in the case of the herring, authorities differ greatly as to the proper way of reading the vital hieroglyphics. Some haddocks grow to a large size, as we have mentioned, and attain to an age of over a dozen years. But, so far as we know, there is never the least trace of ageing or senescence. The old haddock dies young, and some people who pay a wise attention to the character of their food say that the haddocks that are best on the table are the big "jumbos," as they are called. It may be noted that the large-sized haddocks from Iceland waters, which are much sought after for curing purposes, seem to represent a distinct race or variety, differing in slight, yet practically important features from the ordinary North Sea



After Harold Thomson.

SCALE OF A HADDOCK.

This scale was taken from a haddock about sixteen inches in length. It shows eight rings of growth, but it is possible that three of these are not annual. Reading the scales of fishes is often very difficult, and requires to be checked by other data.



COD AND HADDOCK CONTRASTED.

The upper figure (I) is the Cod (*Gadus morrhua* or *callarias*). The lower figure (II) is the Haddock (*Gadus æglefinus*). They illustrate how like one another two distinct species may be; and it must be remembered that a large haddock may be the size of a small cod. It will be noticed that the cod has a long sensory barbule hanging down from the front of the lower jaw; this is very short in the haddock. Above the pectoral fin in the haddock there is a dark patch of pigment-cells ("St. Peter's thumb-mark"); this is absent in the cod. There are many detailed differences of this sort, illustrating what "species" means. Each is itself and no other.

haddocks. There is no reason for supposing that an over-thinning of the North Sea as regards its haddock population would be compensated for by an immigration from the more northerly stock.

The life-history of the haddock is very different from that of the plaice. Both live for the most part on the floor of the sea, but the haddock prefers much deeper water, and is not much in evidence at depths less than ten fathoms. The spawning occurs in the early months of the year, especially from mid-March to mid-April. The eggs and larvæ (about one-sixth of an inch in length) float in the upper layers of the water, and the same is true of most of the fry. But as the summer months pass the young haddocks leave the surface-waters of the open sea and settle down on the bottom. But they are never found along with young cod and saithe, not to speak of plaice, in the shallow waters near shore. Hard and fast statements are impossible, especially as the full-grown haddock is given to roving, but in a general way we must think of this fish as a tenant of the deeper waters of the North Sea—down to a hundred fathoms. Forty per cent. of the North Sea catch is obtained between twenty and thirty fathoms, and fourteen per cent. at fifty to one hundred fathoms.

The young haddock feeds greedily on the smaller animals that frequent the floor of the sea at considerable depths, and it grows rapidly.

At the end of its first year its average size is seven inches, and most of the growing is done in summer. At the end of the second year the average length is a little over ten inches; at the end of the third year twelve inches. Thus we have the usual result that while growth goes on year after year, its annual increments decrease in amount. It is usually when it is three years old that a haddock is ready to spawn and it is estimated that a good-sized haddock may liberate 100,000 eggs in a season. This seems to leave a large margin for safety, but the chances of death are huge.

The eggs are delicate and easily damaged. They are slightly glutinous, and tend to form little groups during their development. They drift about in the sea, and are widely scattered. After about a fortnight the larvæ are hatched out, but the time required varies with the temperature.

Very little is known as to the habits of the haddock. Like other bony fishes it has a brain of a low order, especially as regards its cerebral hemispheres. It is far inferior to the brain of skate or shark or dogfish, which are gristly fishes on a different evolutionary tack. An interesting feature in the haddock's life is the gregariousness, and the fact that the members of a group tend to be of the same age.

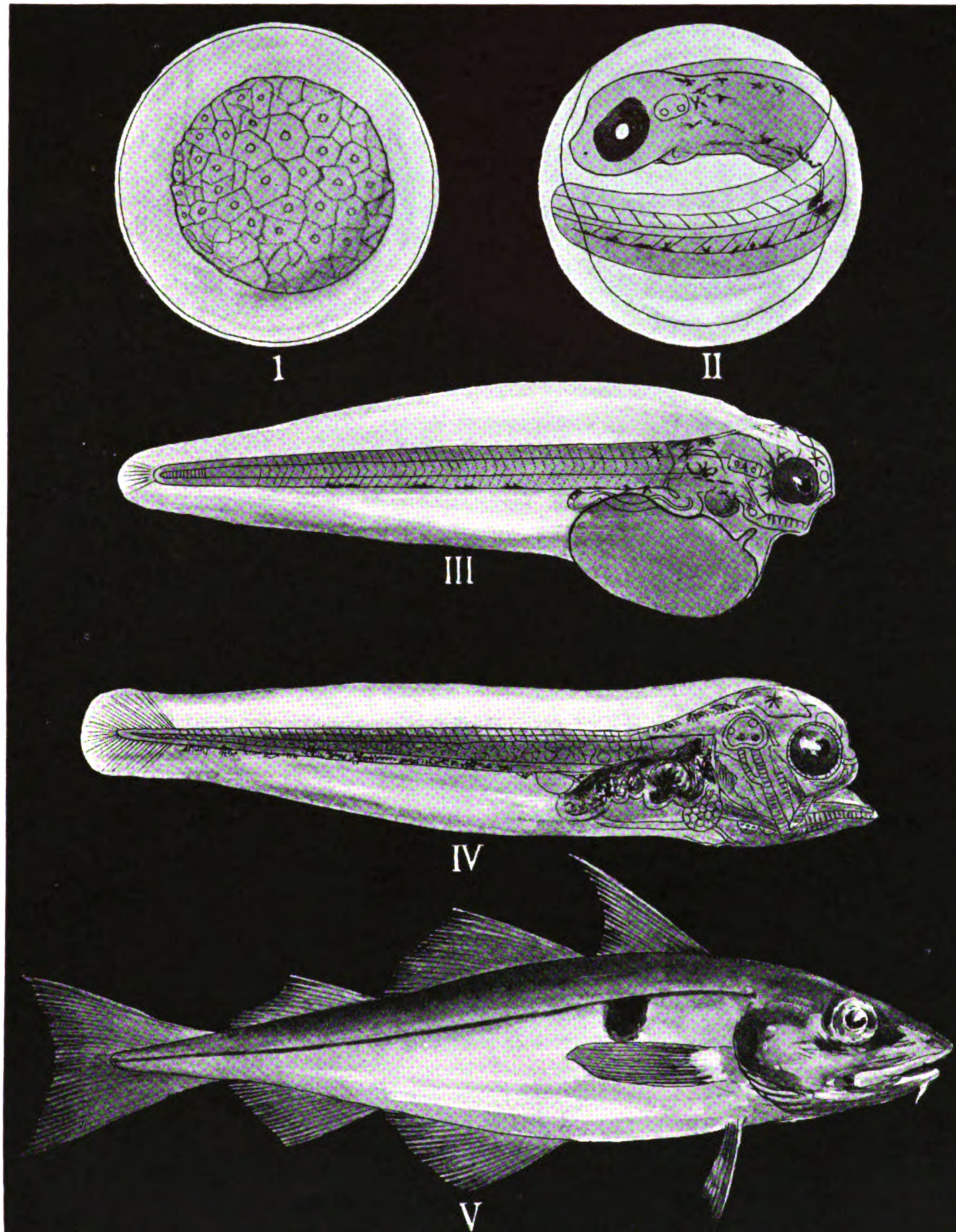
Multiplying Salmon

The life-history of the salmon, which we have described, has many chapters, and each is full of risks. As we have seen, the chancesof death are many; and the salmon in a much-fished river may become scarcer and scarcer, even though a hen-fish of twenty pounds liberates about 17,000 eggs. Thus the question rises: Can anything be done to counteract not only the natural losses but the results of over-fishing. Only a few times in this book has it been possible to sound the practical note, but the salmon is an interesting illustration to take. It is a very palatable and very nutritious food. Although absurdly dear, even at four shillings a pound it is said to be cheaper than cod at a shilling. Moreover, salmon-fishing is a very fine sport. Experts assure us that the yield of salmon in Great Britain could be doubled, if not trebled, in a few years. How could this be done?

Let us begin with a visit that we paid to a salmon-hatchery, not one of the very large ones, but full of interest. There in the month of December we saw the extraordinary process called "stripping" the salmon, which means artificially liberating the egg-cells or ova from the hen-fish and the fertilising sperm-cells (the milt) from the cock-fish.

In a big tank there were about twenty ripe fishes—handsome lusty creatures that had come up from the sea into the swift river that ran past the hatchery. Perhaps they were five years old, and we doubt very much if we could have lifted one, they were so heavy. The expert pisciculturist, who had very strong arms, lifted a salmon out of the tank very carefully, using a half-net, half-basket arrangement at the end of a long pole. Considerable resistance was offered and the fish gave great thuds with its tail. It seemed to be over a yard long, and the expert had to take care that it did not hurt either itself or anyone else. It was emptied out, so to speak, on what looked like a hammock, and there its rebellious behaviour began to subside. Only to begin again, however, when an attendant fisherman put his fingers in behind the gills and gill-cover on each side and lifted the fish bodily upright, steadying it between his knees. The expert hung on to the tail, and by-and-by the living pendulum ceased to swing. There was an interesting change in the colour of the gills, which turned distinctly blue; and it is probable that the salmon passed into a sort of faint. It hung quite still over a tub, and then the expert began a sort of slow massage, gently pressing with his fingers and thumbs along the sides and belly of the fish—always in a tail-ward direction. He tried one fish after another, but nothing happened. Each was put back into the big tank, where it soon began to swim about with what looked like enjoyment of regained freedom and dignity. The males and females were together in the tank, but salmon will never spawn in such artificial conditions.

After a while the expert caught a beautiful ruddy hen-fish, which liberated a cascade of orange-red eggs into the tub—one of the strangest sights one could wish to see. For though it is occasionally possible from a bridge to watch the female salmon shedding her ova into the gravelly furrow, the egg-laying is usually, we believe, in the dark hours. "A cascade



LIFE-HISTORY OF THE HADDOCK (*Gadus æglefinus*).

Figure I. The segmenting floating egg inside its delicate membrane.

Figure II. The egg a few days afterwards, with the unhatched embryo inside, twisted on the bag of yolk. There is an indication of the eye, the ear, the vertebral column, the branching pigment-cells, and other structures.

Figure III. The young haddock just hatched, about one-sixth of an inch in length, with a large quantity of yolk still unused. Eye, ear, heart, muscle-segments and food-canal are shown.

Figure IV. A larva about eleven days old, fending for itself, after the yolk has been quite used up. It is about one-third of an inch in length.

Figure V. A fully formed young haddock that has completed its larval life, which it does when about an inch long. It need hardly be said that the figures could not be drawn to scale.

of eggs" is no exaggeration, for a hen-fish of twenty pounds may yield about 17,000 eggs. The gentle pressure of the expert's fingers and the thumbs liberated the eggs from the ovary, effecting artificially what would come about naturally in the river by the contraction of the salmon's own muscles.

The same "stripping" was done to a male—the expert said he knew the one sex from the other "by the look"; and the sperm-cells of the expelled "milt" penetrated the egg-cells in the tub. This penetration of egg by sperm seems to be extremely rapid—all the eggs are fertilised in a few minutes. The intimate union of the invisible, minutely microscopic, sperm-cell with the conspicuous red-currant-like egg-cell is *fertilisation*, and after that there is the beginning of the individual life of each of the multitudinous offspring.

After the beautiful translucent egg-cells have been fertilised, they are transferred very carefully to hatching boxes, through which a current of well-äerated water flows. Just underneath the surface of the water in these boxes there are trays of parallel glass rods about the thickness of pencils, and the thousands of eggs rest in the shallow furrows between the rods which are almost touching. After a while they will show two minute dark spots—the developing eyes; and then the pisciculturists know that things are going well. The boxes are usually arranged on a staircase plan, so that water flows from one to the other on each stair. The current, however, does not flow over the eggs but at a lower level in the box. Otherwise there would be a jostling of the eggs, and this would be very detrimental. The developing eggs must remain quite still, and they have to be carefully watched lest anything goes wrong, such as an intrusion of microbes or moulds. As we have seen, the development of the salmon proceeds slowly, for the water is very cold; but in three months there is hatching, and in another month or two there are tens—indeed hundreds—of thousands of fry which can be emptied into the river.

In the hatchery we visited the first food given to the fry was bullock's blood, but later on the diet became more substantial. A favourite meal consists of grated egg and minced flesh forced into vermicelli-like threads, for the ittle fishes like wriggly things.

In the natural conditions of the river there is great wastage; it seems that about fifteen per cent. of the eggs are never fertilised, and that another fifteen per cent. never reach the fry stage. And after that there is still great mortality. The object of emptying the artificially hatched fry into the river is to counteract the wastage of life in the early stages, but there are some who believe that it would pay better to rear the young fishes to a later stage—until they are smolts. For the older the fish, the safer it is. Statistics are not very abundant as yet, but they indicate that the return of fry to the river as adult fish is only three to five per thousand, while the return of marked smolts is twenty to thirty per thousand. In some places it would not be difficult to arrange for "nursery streams" in which the fry and parr could grow safely into smolts, sheltered from their natural enemies and with abundant food in the form of insect-larvæ and the like.

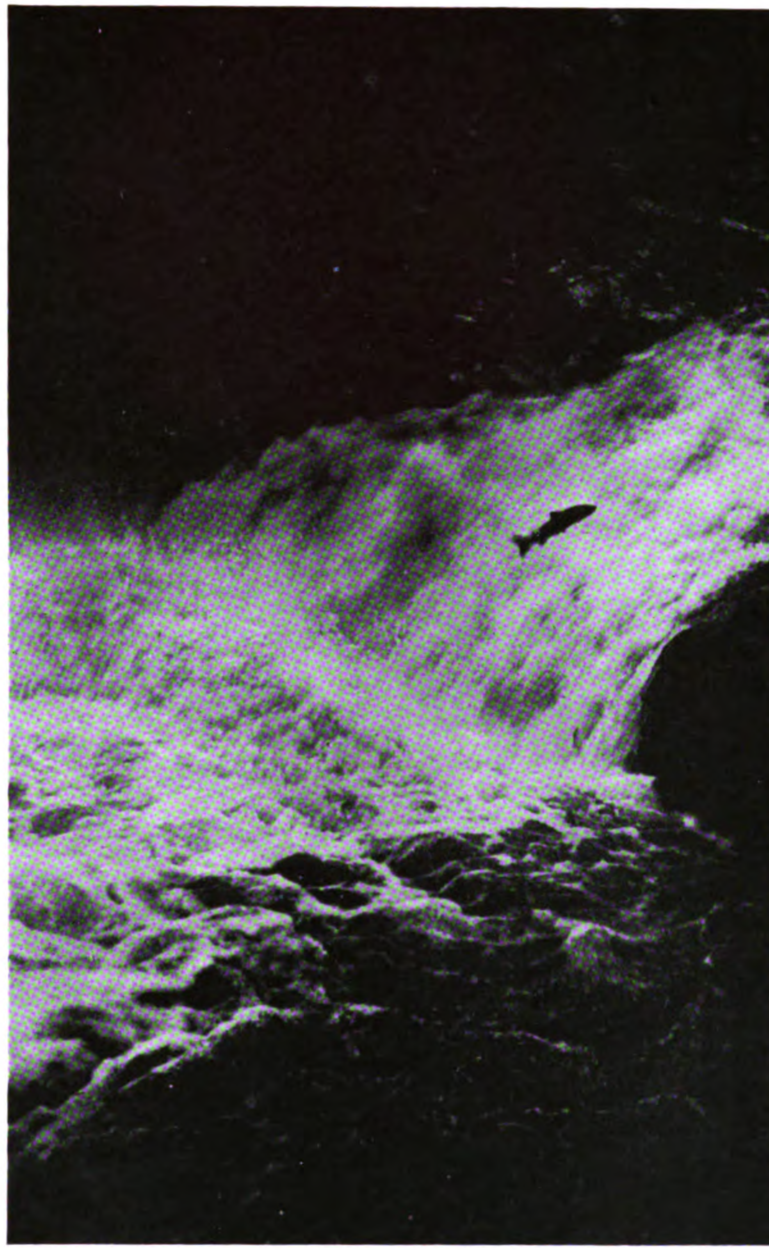
Another practical recommendation that has been made is to plant in the natural spawning grounds some suitable boxes containing "eyed" eggs. This lessens the wastage, and it may be noted that to rear the eggs on to this stage does not require the time, the attention, or the money that is demanded by a properly equipped hatchery for fry.

We need not follow the problem further, for we have taken it simply as an illustration of the control of life which will be increasingly suggested as Natural History grows. It is necessary to have a jealous care of the purity of rivers; it is possible to do something to make rivers richer in their food supply; it is practicable to sow upon the waters and reap a fish-harvest after many days; but there is something more fundamental still, and that is not to kill the goose that lays the golden eggs. Man is always apt to be shortsightedly greedy; he is apt to over-fish. In one of the Pacific Coast States (where there is a different kind of salmon) there is an annual artificial hatching of 186,906,525 eggs, and yet the salmon fisheries are declining. For the fishermen are not leaving a sufficient stock of parent fish each year to secure by their sowing a continuance of the natural harvests. Without this it is vain to look for a multiplication of salmon.

The Turkey

Looking at the poulterers' shops at Christmas time, we wonder if there can be any turkeys left for next year; and we might well doubt this if we were drawing from a wild supply, as in older times. Man could not keep his hands off the wild turkey, and was fast exterminating it; but in the nick of time he threw over it the shield of domestication, and the turkey is safe till the millennium comes with its compulsory vegetarianism.

There is no doubt that we owe the turkey to America, where the wild form (*Meleagris gallopavo*) still lingers. It used to be incredibly common over nearly one-half of the United States, but it was too tempting, and it paid a heavy tax for its palatability. Apart from a recent change for the better, to which we shall refer later on, its range has been persistently restricted, and its numbers have dwindled towards the vanishing point. Dr. Hornaday doubts if even one flock exists in the north anywhere west of Pennsylvania. It is still to be found in some of the open forests of Virginia and Florida, and there are flocks in Texas and Oklahoma.



SALMON LEAPING FALLS.

An interesting photograph of a remarkable feat, a salmon clearing a formidable waterfall. In some cases the heavy body is lifted clean out of the water. The motive power is to be found in the great development of sheer muscle in the posterior body. By lateral strokes or displacements of water a great momentum is acquired before the main leap, and very vigorous strokes are given when the fish sinks back into the stream after its momentary exposure.

It was about 1530 that turkeys were established in Britain and on the Continent, and there is no doubt that they were imported from North America. We are here adopting the view that there is one species of wild turkey in the United States—*Meleagris gallopavo*—with three geographic varieties; but it is maintained by some ornithologists that our black Norfolk breed came from the source we have mentioned, while the more variegated Cambridgeshire breed came from *Meleagris mexicana*, with which it agrees in having its tail-coverts and quills tipped with white or pale yellow.

Quite different, and resisting domestication, is the brilliant Ocellated Turkey of Yucatan, British

Honduras, and Guatemala, a resplendent green bird with beautiful tail eye-spots, worthy of being compared with those of the peacock. We suppose there must be some subtle difference in constitution and temperament between this species and the other, for it is difficult to keep the Eyed Turkey in captivity, while the ordinary species is readily acquiescent. But though acquiescent, the domesticated turkey has surrendered very little to man's whims; it retains on the whole a sturdy independence, except when advantage is taken of the hen's strong brooding instinct to turn it into an incubating machine for fowls' eggs. No bird can stand brooding month after month!

"The king of upland game-birds" the wild turkey has been called. A large male may be forty-six inches in length and twenty-eight pounds in weight. Their flight to the roost-trees is powerful and silent, with not more than "a soft *swish-swish*" of the large wings. Mr. Archibald Rutledge notes that in mountainous country, turkeys do a good deal of sailing down long slopes, and get up a speed of about a mile per minute. "This wild volplaning is a most beautiful and impressive sight. The birds' wings are set to curve slightly downward, and the rush of the wind through these makes a sound like a howling shrapnel." There is some safety in the lofty roosts and in the rapid flight, but turkeys spend most of their daylight hours on the ground, searching for seeds, fruits, and other parts of plants, with an occasional insect or lizard for relish. At these times their safety depends on quick running and keen senses. It is said that there has been a very notable increase in wariness since the numbers were so much reduced. Vision and hearing are extraordinarily acute; the most trifling movements and sounds are detected at once.

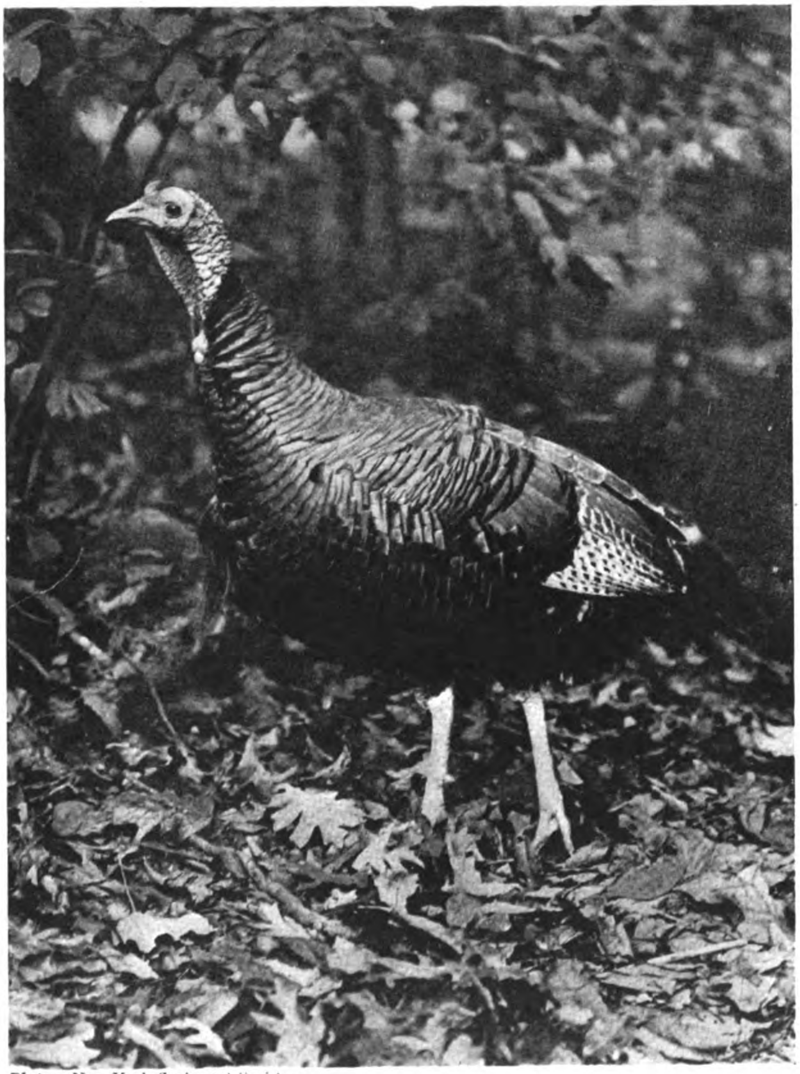


Photo: New York Zoological Society.

FEMALE WILD TURKEY (*Meleagris gallopavo*).

During a large part of the year the cocks and hens live apart, but they come together in flocks in the winter months when they seek the more sheltered valleys. They feed on seeds, fruits, grass and small animals. The hen is a very good mother and leads her young flock about for months, defending them with courage. According to some authorities the domesticated turkey of Europe has had a double origin in the two North American species or varieties, the Northern *Meleagris gallopavo* and the Southern *M. mexicana*. But there is not very much difference between them.

The sportsman's plan is to discover the bird's line of advance and wait for him patiently. As Mr. Rutledge says: "The only real way to stalk a wild turkey is to have him

Photo: *New York Zoological Society.*

MALE WILD TURKEY (*Meleagris gallopavo*).

This handsome bird was once at home over nearly one half of the United States, but it is now for the most part restricted to very wild and densely wooded regions. In a few places it is again on the increase. Almost the only difference between the wild Turkey Cock and the domesticated form is that the tame bird has sometimes a great splash of white above the root of the tail, on the feathers called the tail-coverts.

stalk you." When they are off their guard they make a good deal of noise themselves, shuffling among the leaves, and, like our capercailzies, they often knock clumsily against branches when they take to flight. They avoid dense undergrowth and frequent the open glades, sometimes venturing on to cultivated land. They seem to be very hardy, ascending even to 10,000 feet.

In both sexes the head and neck are almost naked, there are livid wattles, and the forehead bears a long pendulous process or caruncle which stands upright when the birds are excited. The male is distinguished by his larger size, his strong spur, and a bunch of long black bristles on his chest. In the wild state the cocks fight fiercely in the spring, each trying to secure at least one hen. In this country we are more familiar with their strutting about before their desired mates—the raising of the tail into a gorgeous wheel, the drooping of the quivering wings so that they sometimes scrape the ground, and the uttering of curious puffing and gobbling noises. The word turkey refers not to the "gobble," but to the ordinary call-note *turk, turk*; for, like some other creatures, this bird is always repeating its own name.

After the pairing the cocks and hens separate, and a nest is made in a well-concealed corner. It is lined with dry leaves, which are shifted over the ten or more eggs when the brooding bird has to leave them for a hasty meal. The turkey hen is a devoted mother, taking great care to keep her chicks dry and well fed. A bird that nests on the ground is always at a disadvantage, but the wild turkey hen does all she can to hide the nest and the eggs and to protect the young. This maternal virtue goes so far that it is safe to say that if man's persecution had not been so extreme the wild turkey would be as common as it is rare to-day. In the fall of the year the cocks and hens unite in flocks, and move

Photo: New York Zoological Society.

NEST OF WILD TURKEY

Turkeys roost in trees, but nest on the ground amidst dense undergrowth. The nest is a simple collection of withered leaves and the like. The large eggs are often from nine to fifteen in number. At the brooding time the hens keep by themselves, and they afterwards lead the young birds about in little flocks, carefully keeping out of the way of cocks, who do not seem to be friendly to their offspring.

about in the winter months searching for food.

According to Darwin the fleshy process on the turkey's forehead is simply an ornament that stands upright as a symptom of excitement at the time of courtship. According to Mr. J. T. Cunningham, who believes in the transmission of the results of blows and strains, the caruncle is connected with the combats of the cocks. If there is anything in this theory it is necessary to suppose that the caruncle has secondarily become part of the hen's inheritance, for the hens do not fight. There is no doubt that the lusty cocks fight with some ferocity, striking at the head and gripping one another by the wrinkled wattled skin of the neck. We do not ourselves believe that the direct results of peculiar exercises of this sort can be entailed, even in a representative degree, on the offspring; but this is a question in regard to which we should keep an open mind. Therefore we wish to state Mr. Cunningham's deliberate conclusion: "In all probability the naked head and neck of the turkey, with the blue and red wattled skin and long fleshy process, are to be regarded as exhibiting the inherited scars of a long line of pugnacious ancestors."

Turkeys are obviously very muscular birds, but they do not usually fly far. When the wild birds are migrating in search of food they go afoot. When they come to a broad river, they settle down and think over the question. After some noisy consultation, which may last for days, the leader gives the signal, and they all mount to the tree-tops, and thence take wing. They are not very confident, however, in their flight, and some tumble into the water. Yet they are better swimmers than one would think, and the crossing is usually effected in safety, though often with bewilderment. Turkeys do not seem to be birds of great intelligence, even in their wild state, and

domestication has not improved matters. Apart from their amorousness at the breeding season, the strongest point in their character is the maternal care, which is very marked. Perhaps it is the feminine expression of masculine passion. The care is purely maternal, for the hens go apart before egg-laying begins. It is said that the males, who are emaciated after the love season, will devour the eggs if they find them.

One of the interesting facts in regard to the wild turkey in the States is that it is at present on the increase. It has been on the verge of extinction, but now it is coming back, "diffidently perhaps, but none the less certainly," to some of its old haunts. Thus Mr. Archibald Rutledge reports from Pennsylvania the presence of flocks of two dozen or more. This is good news, for there is a certain splendour about this largest of game-birds, and the gobbler in the forest strikes a note of wildness that is precious in these sophisticated days.

Domestication does not seem to have effected very striking improvements in the turkey; in fact, breeders have to watch against a tendency to going back in size, vigour, and decorativeness. One of the frequent results of the domestication of animals has been to extend over a long period what is in natural conditions restricted to a short one—the egg-laying of poultry and the milk-production of cattle being familiar examples. Something similar is illustrated in the case of turkeys, for the hen is trained to brood month after month on successive clutches of the eggs of fowls, or to act as foster-mother to many successive sets of chickens. This is apt to be exhausting. Very interesting in another direction is the turkey's strongly ingrained instinct to roost in a tree at dusk—an instinct which has sometimes disconcerted a farmer

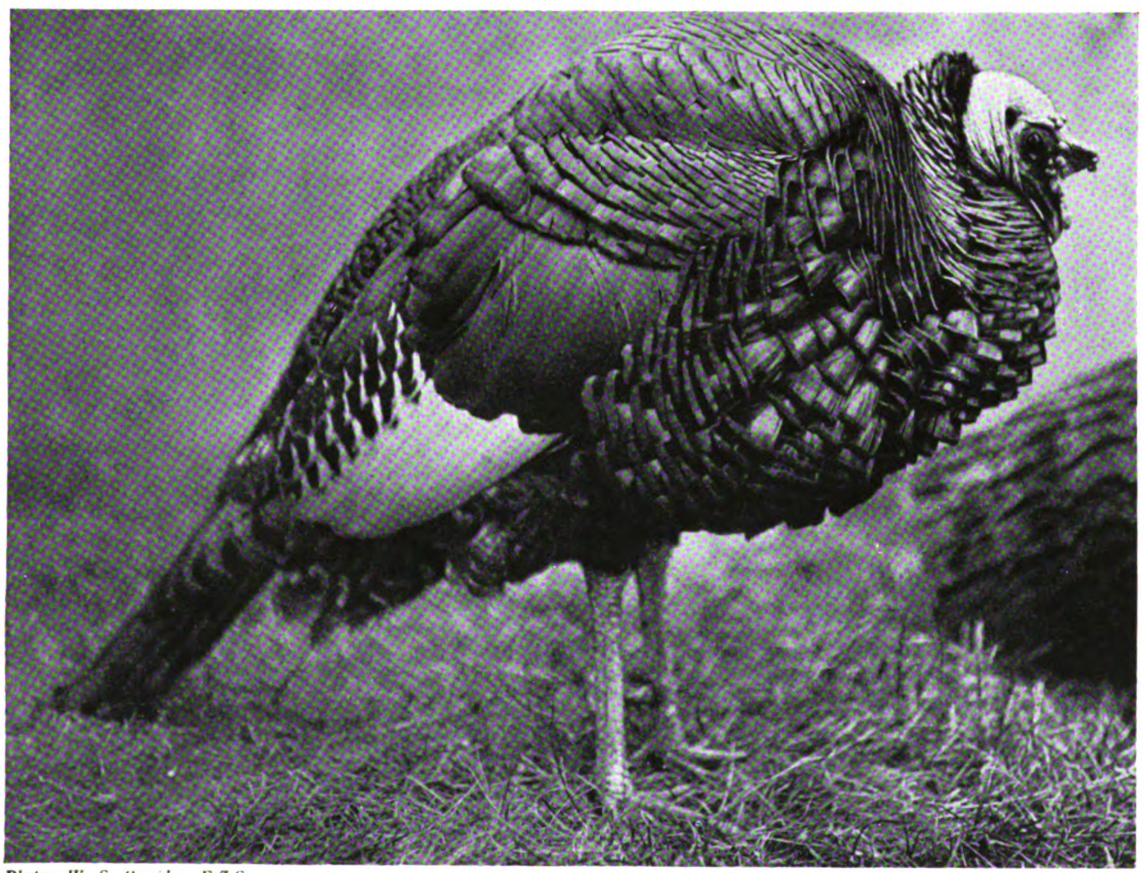


Photo: W. S. Berridge, F.Z.S.

OCELLATED OR HONDURAS TURKEY (*Meleagris ocellata*).

One of the most gorgeous birds in the world, found on the borders of Guatemala and British Honduras, rather smaller than the other turkeys, but approaching a peacock in its splendour. The bare skin covering the head has a deep blue colour, studded with orange knobs. Most of the plumage is metallic green, but there are blue and purple " eyes " on the tail. This bird does not usually thrive in captivity.

Photo reproduced by courtesy of "Poultry.

CAMBRIDGESHIRE TURKEY COCK.

The Cambridgeshire breed of turkey is more variegated in colour than the Norfolk breed. Some parts of the plumage have a bright metallic gloss; the tail-coverts are tipped with white or light yellow: the chicks are usually mottled with brownish-grey. According to some authorities, this breed is descended from the Wild Turkey of the southern United States, which is often distinguished as *Meleagris mexicana*.

driving a flock of turkeys along a road in the evening.

The most important steps in domestication and cultivation are prehistoric; and we know very little about them. Thus the when, the where, the whence and the how of the domestication of cattle, horses, and sheep remain obscure; and the same must be said in regard to the origin and history of most of the directly useful cultivated plants. In a few cases something precise may be said, as, for instance, that most of the races of cultivated wheat may be traced back to the Wild Wheat which still grows on the shoulder of Mount Hermon. Or one may derive the domestic dogs from several species of wolf. Or, similarly, it is generally admitted that the multitudinous breeds of domestic fowls can be traced back to *Gallus bankiva* of India and Malaya, as the domestic pigeons to the wild Rock Dove.

Domestication and Cultivation.

But whether the origins are less or more obscure, it may be safely said that biology as such has not yet contributed much to domestication and cultivation. Perhaps the list of the domesticated is for intrinsic reasons short, perhaps modern man is lacking in prolonged patience, perhaps, in the case of domesticated animals, he has lost the art by losing his subconscious sympathy with the creature. Our point is that the more important conquests were made before the days of science.

ORIGIN OF THE DOMESTIC DOG

One of the many fine things that prehistoric man did was to domesticate the dog—which became the trusty guardian of his flocks, his partner in the chase, the sentinel of his home, and much more besides. That our ancestors turned a wild dog into a tame one is certain, but we do not know how they managed it, or how often they did it, or how many different wild stocks they used.

Of wild dogs in the strict sense, belonging to the genus Canis, there are three groups, all gregarious—(1) the Coyotes, or prairie wolves of North America; (2) the Jackals; and (3) the True Wolves of the Old World. Some authorities are of opinion that the domestic dogs arose from each of these groups independently, so that there are coyote-dogs, jackal-dogs, and wolf-dogs. Most authorities are inclined to exclude the coyote as an originator, though they would not deny that its blood may have mingled with that of domesticated dogs originating in the Old World and afterwards taken to America. This is one of the many uncertainties.

The best-established view is that the domestic dogs of the Old World arose mainly from *small southern wolves*, but that there may also have been an origin from grey jackals (*Canis lupaster* or *sacer*) or from wolf-jackals (*Canis anthus*). It seems very unlikely that the Common Jackal (*Canis aureus*) of North Africa and other parts had any share in credit of giving origin to domestic dogs.

When an unprejudiced person is told for the first time that the domestic dog is descended from a wolf, he is inclined to be incredulous. For the dog's nature seems very different from that which we are accustomed to associate with wolves. It is probable, however, that a considerable part of the popular picture of the fierce wolf is hearsay Natural History. Dr. Antonius, in his book on Domesticated Animals (1924), quotes from one of the most experienced of European huntsmen who had in fifty years known of only one case of wolves attacking a man! In thinking of wolves we shall be guided to some extent by the insight of the pictures given in Kipling's "Jungle Book."

An interesting point about wolves that are born and bred in captivity is that the unusual conditions of their upbringing leave their mark on the characters of the skull and teeth, often bringing them nearer those of domestic dogs. It is not likely that the change from wolf to dog came about in this direct way, but it is interesting that a very considerable change can be effected in the course of one generation. Perhaps it makes it easier for us to understand how thousands of years of careful sifting and breeding

from among the new departures or variations that are always cropping up, have resulted in establishing the differences not only in skull and teeth, but in temperament too, that separate dog from wolf, and that distinguish the numerous races of domestic dog from one another.

The dog was one of the first animals to be domesticated, and probably the first. This took place in the early Neolithic Age when man was still using stone weapons—though of a finer type than before. The question rises how we can say anything about the early chapters in the dog's partnership with man, seeing that it began so long a time before history. The answer is that there are a great many remains of "prehistoric dogs" in caves and about lake-dwellings and even burying places. To some extent it has been possible to piece out the prehistoric history.

The oldest known European domestic dog is called, after its discoverer, Studer's Stone Age dog (*Canis putiatini*), a dingo-like or pariah-like animal about the size of a collie. It was found in a Stone Age settlement near Moscow, and there is much to be said for regarding it as the ancestor of *most* of the breeds of domestic dog.

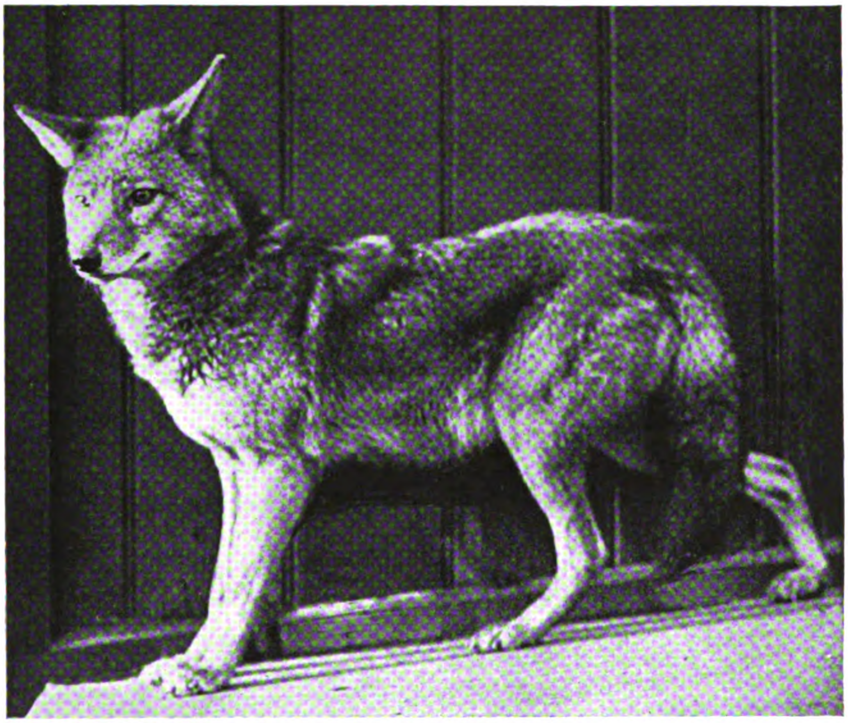


Photo: F. W. Bond.

NORTH AFRICAN JACKAL (*Canis anthus*).

Larger than the Common Jackal, more elegant, with long legs suggesting those of a greyhound. It has a bright tawny colour with dark bands. In disposition it is shy and suspicious, and it does all its hunting under cover of darkness.

There were some other very old "prehistoric dogs," but it is probable that most of them can be traced back to Studer's Stone Age dingo-like dog. Thus, there was the old-fashioned peat-dog, *Canis palustris*, whose remains are found near Neolithic lake-dwellings in Switzerland. Among its representatives to-day may be mentioned the Scotch terrier and the Siberian or Samoyede dog, usually of a beautiful white colour. Then there was the "intermediate dog," *Canis intermedius*, also from Neolithic remains, almost certainly a descendant of Studer's Stone Age dog. It is represented to-day by hunting dogs that follow by scent, such as foxhounds and setters.

Another prehistoric dog, bearing the quaint, but rather beautiful, name of "Best-Mother dog" (*Canis matris optimæ*), has been found in Bronze Age stations, and it seems to have been the ancestor of sheep-dogs. It leads to old-fashioned forms like the Belgian sheep-dog, and onwards to finer races like the Collie and the Alsatian.

So far, then, we can make a provisional genealogical tree:—

e.g., Foxhounds	e.g., Collies and Alsatians.	e.g., Scotch Terriers.
↑	↑	↑
"Intermediate Dog"	"Best-Mother Dog"	"Peat Dog"
↑	↑	↑

Studer's Stone Age Dog

↑

A small Southern Wolf.

Photo: F. W. Bond.

ASIATIC JACKAL (*Canis aureus*).

Distinguished from a wolf by its much smaller size, thirty inches in length, and by its long pointed muzzle, the Common Eastern Jackal is a well-known carrion-eater, and of some service as a scavenger. The prevalent colour is dusky yellowish. Jackals hunt in packs, bold rather than brave, voracious and noisy, thievish and clever. They can be tamed. but they have a vile smell.

Photo: F. W. Bond.

PALÆARCTIC WOLF (*Canis lupus*).

What many regard as one species of wolf is widely distributed in Europe and Asia—a fierce carnivore, usually solitary in summer and gregarious in winter. It is about five feet long from tip of snout to tip of tail, but the tail, which is held straight down, counts for about twenty inches. A wolf howls, but never barks. There were wolves on Dartmoor during the reign of Queen Elizabeth, and they persisted in Scotland till 1743.

But the pedigree of domestic dogs is not so simple as our scheme suggests. Some of the skulls of prehistoric domestic dogs have wolfish characters combined with those of Studer's Stone Age dog, or with those of one or other of its three descendants. There is general agreement among experts that apart from the actual origin of Studer's Stone Age dog from a small southern wolf, there has been additional admixture of wolf's blood. This is especially true of some of the strong forceful races that are not merely "watch-dogs" or "shepherding dogs," but courageous defenders of the flock against the attacks of wolves. Just as the reformed poacher would probably make the best gamekeeper, if he got a chance, so it is likely enough on general grounds that crosses between wolves and domestic dogs would result in courageous defensive types. A wolf is loyal to its pack, and the domesticated dog probably accepted man as an unusual but admirable kind of leader, who commanded and deserved obedience and faithfulness.

There is evidence from the complex minglings of skull characters that early forms of domesticated dog were crossed with wolves. This is said to be true of some of the fiercer or sturdier races, such as the Siberian "Laikis," the English "Bobtails," the curly-haired Hungarian sheep-dogs, the Saint Bernards, the Molossus-dogs of Albania, and the Leonbergers of South Germany. This does not happen nowadays, so far as we know, for the wild and the tame do not usually like one another, and even if there is pairing there are no offspring.

The pedigrees of many domesticated animals turn out to be much more complicated than used to be supposed, and this is very true of the dog. Dr. Antonius, who has recently given much attention to the history of dogs, tells us that greyhounds probably arose to the south of the Mediterranean from a wolfish ancestor of the present-day Pariah dogs, perhaps with the assistance of the North African Wolf-jackal (*Canis anthus*). But many of these greyhounds were taken north into Europe, where their stock was probably strengthened by crossing with some of the dogs that had wolf's blood.

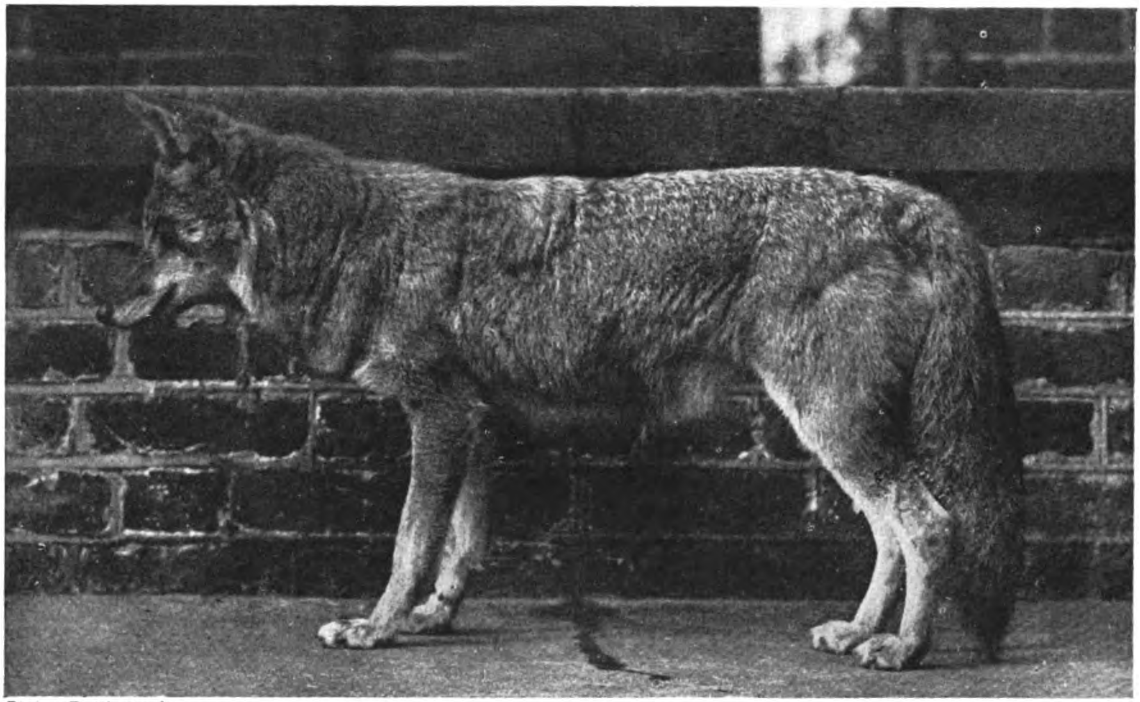
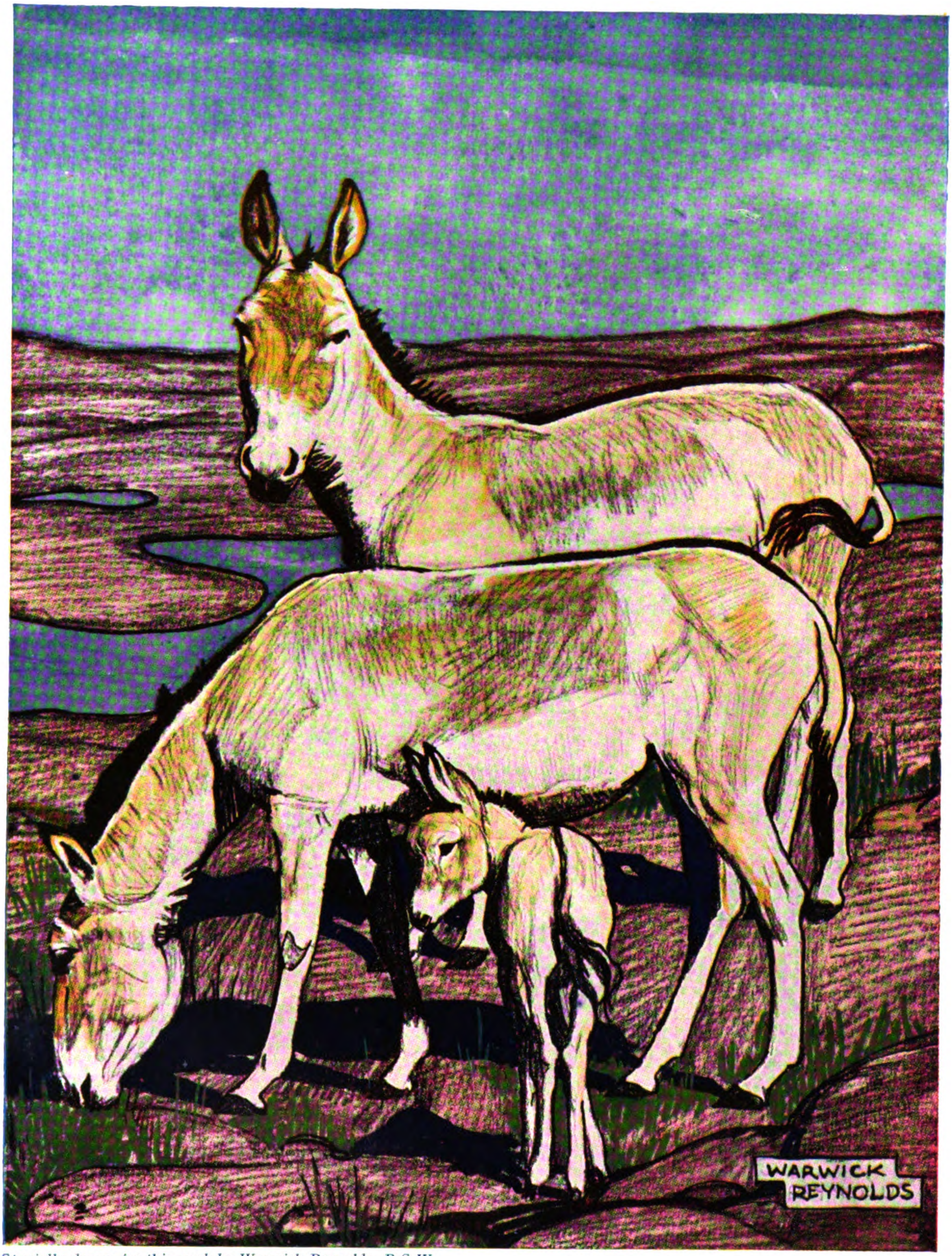


Photo: F. W. Bond.

PRAIRIE WOLF OR COYOTE (*Canis latrans*).

This American wolf ranges from Mexico northwards through the Great Plains and Rocky Mountain region to Alberta. Its name—latrans—means "barking," but experts do not credit it with more than a "dog-like yelping, half-howl and half bark," very different from the "prolonged and steady deep-bass howl" of the American Grey Wolf, which is nearly related to that of Europe. Coyotes may be troublesome, but they are useful in keeping down "prairie-dogs" and other rodents.



Specially drawn for this work by Warwick Reynolds, R.S.W.

THE ONAGER (*Equus onager*).

The best known of the Asiatic Wild Asses, at home in Persia, the Punjab, and the country of Cutch. A swift creature of the great expanses, uniformly yellowish like the desert background, it is apparently tameable and a probable ancestor of some domestic donkeys.

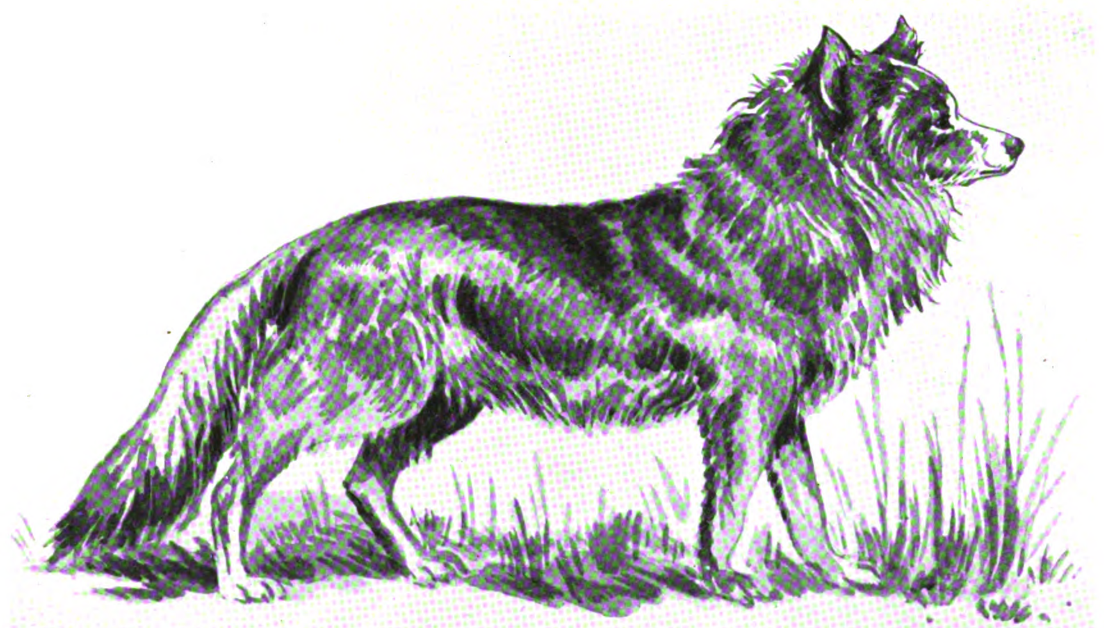
With the ebb and flow of peoples, such greyhounds were again taken to the south. It is this sort of crossing and re-crossing that makes the deciphering of pedigrees so very difficult ; and we are lingering over the problem because it must serve as an illustration of what is true in many other cases.

When America was discovered by Europeans there were already many kinds of domesticated dog. Those of the Incas, for instance, were of sheep-dog, dachshund, and bulldog types, and the question is where they came from. Some authorities have maintained that some or all of the North American dogs arose from a prairie-wolf or from a true wolf ancestry, but the general view nowadays is that explorers of ancient days, coming from the north a very long time before Columbus, while a land passage across the Behring Strait was still possible, *brought Old World dogs with them.*

Conclusion. Let us sum up this long and difficult, but very interesting, story. If we ask where a Collie or an Alsatian or the like came from, the probable answer is that it may be traced back to " the best-mother dog," *Canis matris optimæ*, But this ancestor of sheep-dogs can probably be traced back to Studer's Stone Age dingo-like or pariah-like dog (*Canis putiatini*). But where did Studer's Stone Age dog come from ? As we have frankly admitted, there is as yet no certainty ; but the probability is that Studer's dog was descended from a smallish species of wolf. After domestication had been effected, and other domestic dogs, like the " peat-dog," the " intermediate dog," and the " best-mother dog," began to arise from the dingo-like stock, the probability is strong that there was, in some cases, further crossing with northern wolves and also (in the case of greyhounds) with grey-jackals.

The domestic dog is a credit to man, but the domestic cat is a conundrum. Has any human being the hardihood to say that he or she understands a cat ? Affectionate but capricious, attached but reserved, proverbially tame and yet with hidden wildnesses, sociable yet walking alone, what a bundle of inconsistencies is a cat ! The Domestic Cat of Europe is probably the descendant of the Caffre Cat, *Felis caffra*,

The Natural History of the Cat.

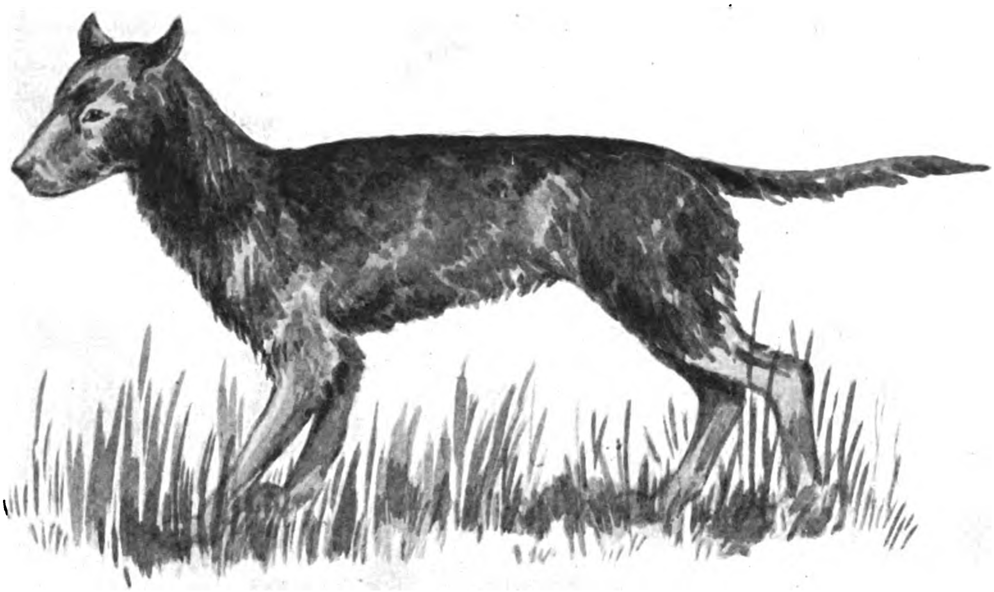


Drawn by Miss E. Bonn, under direction of Edward C. Ash.

ATTEMPTED RESTORATION OF THE PREHISTORIC STONE AGE DOG.

The oldest known European domestic dog, Studer's Stone Age Dog, was found in a Stone Age settlement near Moscow. It was a dingo-like or pariah-like animal, about the size of a medium Alsatian, and was probably the origin of most of the subsequent races.

which the ancient Egyptians tamed and mummified. Some authorities think they got it from Persia or Babylon. But other domestic cats, like those of China and India, seem to have been derived from other wild species, and the lineage has been complicated by crossing with various wild cats. The African Caffre Cat, the Indian wild cats, and the European Wild Cat will all breed with the domestic cat. Besides the complications due to multiple origin and to crossing with wild species or wild ancestors, there is another source of confusion that domesticated individuals readily resume wild ways, becoming " feral," as it is said. The British blood of our Wild Cat in their veins. Apart from subtle differences between the Wild Cat and the Domestic Cat, such as that the soles on the hind feet of the former are not quite black, there are two common-sense reasons against the theory that our Wild Cat was the direct ancestor of our Puss. The first is that the Wild Cat is a very intractable creature. As to this, Mr. Millais writes: " Lynxes, leopards, and lions may all become amenable to discipline, but the Wild Cat always has his back to the wall, ears down, eyes glittering, and paws ready to strike. Well-named, it is the real untamed and untamable savage." It is quite otherwise, Professor



Drawn by Miss E. Bonn, under direction of Edward C. Ash.

ATTEMPTED RESTORATION OF THE PREHISTORIC PEAT-DOG.

This old race, *Canis palustris*, probably sharing a common ancestry with Studer's Stone Age Dog, or derived from it, is known from remains found near Neolithic lake-dwellings in Switzerland. Among its modern representatives may be reckoned the usually white Siberian or Samoyede dog and the Scotch Terrier.

Wild Cat, *Felis catus*, which lingers in Scotland in secluded places like Ardnamurchan and the shoulders of Ben Wyvis, is an *improbable*, but not an impossible, ancestor of the domestic cat. There are marked differences, such as the short and clubbed tail, but some authorities regard these as indecisive. Perhaps a compromise between the discrepant views might be found in saying that our pussies originated in the Caffre Cat (*Felis caffra*), which we do not distinguish from the Nubian Falb Cat (*Felis maniculata*), but that they have some of the Keller points out, with the Nile Valley cat, for even to-day wild kittens are brought into the village houses in Nubia and North East Africa. They are readily tamed, and are useful in checking the ravages of small rodents. The other argument against looking for Puss's ancestry in the Wild Cat is that the domestic form was for a long time rare and valuable in countries like ours, where the Wild Cat was at home. The story of Dick Whittington's cat is proof enough. The learned say that the very word " Puss " takes us back to Egypt.

Drawn by Miss E. Bonn, under direction of Edward C. Ash.

ATTEMPTED RESTORATION OF THE PREHISTORIC INTERMEDIATE DOG.

Another prehistoric dog, whose remains are found in Neolithic deposits, is called the "Intermediate Dog" (*Canis intermedius*). It was almost certainly a descendant of Studer's dingo-like or pariah-like dog, and is represented to-day by hunting dogs that follow by scent, such as Foxhounds and Setters.

Drawn by Miss E. Bonn, under direction of Edward C. Ash.

ATTEMPTED RESTORATION OF "BEST-MOTHER" DOG.

A fourth prehistoric dog, technically called *Canis matris optimæ*, the dog of the best mother, is known from remains in Bronze Age stations, and was probably ancestral to the sheepdogs, first to more primitive forms, like the Belgian sheepdog, and then to the highly evolved Alsatian and Collie.

From the Natural History point of view, the cat has no end of interesting features, and Professor St. George Mivart wrote a big book (" The Cat," 1881) in which the feline framework was used as an introduction to the study of mammals. Let us select a few features. On each side of the cat's upper lip there are about a dozen strong whisker-hairs, technically called vibrissæ. The bulb at the base of the hair is entered by nerve-fibres, so that each serves as a touch organ. There are some other sensitive hairs near the wrist.

When we look at a cat's fore-paws we see seven pads, gripping cushions of fibrous tissue and fat. Four are close together in front, corresponding to digits II to V ; then comes a large three-lobed pad, corresponding to the ends of four palm bones (metacarpals) ; a little farther back to the inside is the small pad for the thumb ; on the opposite side, a little farther back still, is the pad corresponding to one of the bones of the wrist. So that makes seven. On the hind-paw there are four pads for the four toes (II to V), and a large three-lobed one for the end of the sole-of-the-foot or instep bones (the metatarsals). There is no big toe, except in so far as that is represented by a dwindled metatarsal. Of more importance is the almost vertical position of the bones of the sole and palm, for this gives the cat and all its kindred a highly developed tiptoe (digitigrade) way of walking, so different from what we see in bears, for instance, or in ourselves. The members of the cat tribe are always, so to speak, on tiptoe, mentally as well as regards their bones. We must not continue in this anatomical vein, but we cannot leave pussy's foot without mentioning the claws of steel within the velvet glove. The claw or sharpened nail, borne by the last joint of each finger, is drawn back into a sheath on the outer side of the second last joint by a very elastic ligament, which keeps it in this position when the cat is resting or walking. When the need for action comes, the claw is drawn forwards and downwards by the backward pull of a long flexor tendon which runs along the under-surface of the finger, and is worked by a strong flexor muscle above the wrist. The same holds for the hind-feet, but the claw is drawn back on to the upper-surface of the second last toe joint. The net result is that the retractile claws are kept sharp in their sheaths, and this is characteristic of all true cats.

Photo : Humphrey Joel.

FOXHOUND.

The outcome of very careful selective breeding, with especial reference to speed, endurance, sense of smell, and educability in giving voice when on scent or keeping silent when not. Among its features may be noted the large head, the strong, short back, the long graceful ears, and a white colour with black or tan markings.

One of the interesting points about a cat's eyes is the change in the shape of the pupil when the iris contracts in bright light. The pupil, which is the open window surrounded by the

Photo : Sport and General.

SCOTCH TERRIER.

A favourite breed of dog, compact in build, short of leg, with a short, thick, firm coat, with erect ears and an intent expression. The Scotch Terrier, practically the same as the Skye Terrier, is a clever, energetic, cheerful dog, whom to know is to like.

Photo : Sport and General.

COLLIE.

An invaluable sheep-dog of ancient origin. Among its marks may be mentioned the long head, narrowing in the snout, the keen eyes set rather close together, the small ear drooping slightly at the tip. Greater importance, however, attaches to its cleverness, educability, and devotion.

Photo : Sport and General.

ALSATIAN WOLF HOUND.

A breed that has become a great favourite of recent years, and deservedly because of its combination of good qualities—strength, loyalty, alertness, and good-temper. Its wolf-like head suggests some recent introduction of wolf's blood, but there seems no secure evidence of this in well-bred types. It is probably no nearer a wolf than a Scotch Collie is.

Photo : Sport and General.

BLOODHOUND.

A breed famous for its fine sense of smell, especially in following a wounded animal from which blood drops. The Bloodhound is large, strong and tan-coloured, with long ears and with a dignified, strong head. In some cases they have been successfully used in tracking murderers.

Photo: H. M. Bell.

TABBY CAT.

There is great variability in the colouration of domestic cats, even within a litter. A Tabby Cat is just a colour variety, predominantly grey, with black streaks on the back, and parallel dark curves on the sides and thighs.

Even when we keep to the strictly biological, there are many puzzles about the cat. Thus white cats with blue eyes are generally deaf, and true tortoiseshell cats are usually females, the former fact more of a puzzle than the latter. The brother of a tortoiseshell female is sandy. There seem to be two main types of pattern among domestic cats, when there is any pattern at all. In the one, the head is striped longitudinally and the body

coloured iris, is circular in the great majority of domestic cats, but it is sometimes a pointed oval, or between these two shapes. When a lion or a tiger comes into the glare the pupil in front of the lens contracts to a small circular opening; but in the cat, as also in genet and civet, the pupil contracts into a vertical slit with two pin-holes, one above and one below. The use of the contraction is to prevent over-illumination of the eye, but the particular shape that results is an idiosyncrasy. In the back of the cat's eye, in the layer called the choroid, there is a circular patch of a golden-yellow colour, called the tapetum. It has the power of reflecting light, and it accounts for the cat's eyes "shining in the dark." There is no light-production, only light-reflection; but the tapetum may be of service in enabling the cat to make the most of a little light. In a true "dark room" the cat's eyes do not shine.

Photo: H. M. Bell.

TABBY'S HEAD.

This photograph of a familiar subject shows very clearly the vibrissæ or sensitive "whisker-hairs," which are of great importance to cats in their nocturnal hunting. They are exquisite touch-organs, with an intricate innervation of their swollen roots.

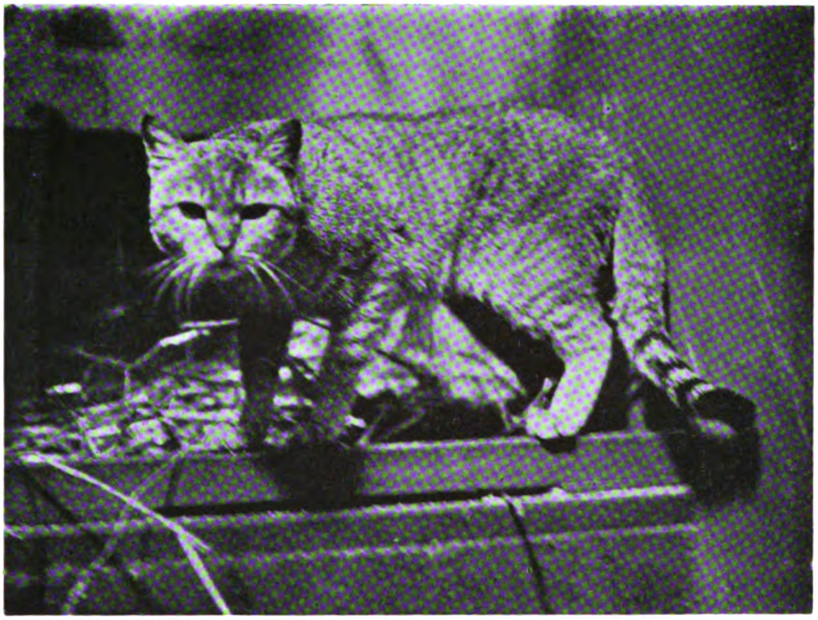


Photo: W. S. Berridge, F.Z.S.

CAFFRE CAT (*Felis caffra*).

A South African wild cat which is regarded by some authorities as one of the ancestors of the Domestic Cat, or of a domesticated race of cats. Crosses between the common Domestic Cat and the Caffre Cat are said to occur, yielding fertile offspring.

variety is unknown, but it probably arose as a sport or mutation. It is interesting to notice that varieties with very short tails have been reported from various parts of the world. Then everyone knows the beautiful Angora variety of Asiatic origin. Its long silky hair may be a variation suited for a cold mountainous home. Finest of all are the Siamese cats. The kittens are brilliant white albinos with pink eyes, but as they grow older the fur becomes a curious fawn colour and a little pigment appears in the eyes. They are good mousers, very clever

transversely, as in the Caffre Cat. In the other, the " tabby " type, there is a grey ground-colour on which vertical and wavy black bands are almost concentrically disposed on the flanks and thighs. Where the " tabby " pattern came from we do not know; it does not *blend* with the striped pattern, and the two types may be seen in one litter, illustrating what is known as Mendelian inheritance.

Another interesting question is that of varieties, but it is extremely difficult. There is the Manx variety without a tail, with very high hind-legs and a big head. In a cross between a Manx and an ordinary cat, the absence of tail proves to be what is called an imperfect dominant. That is to say, some of the litter have no tail, others have a short one. The origin of this Manx

and usually reliable.

The Natural History of the cat is full of puzzles, but its psychology is an unknown quantity. It requires audacity to write about it. In a kind of way we understand a dog; it has accepted man

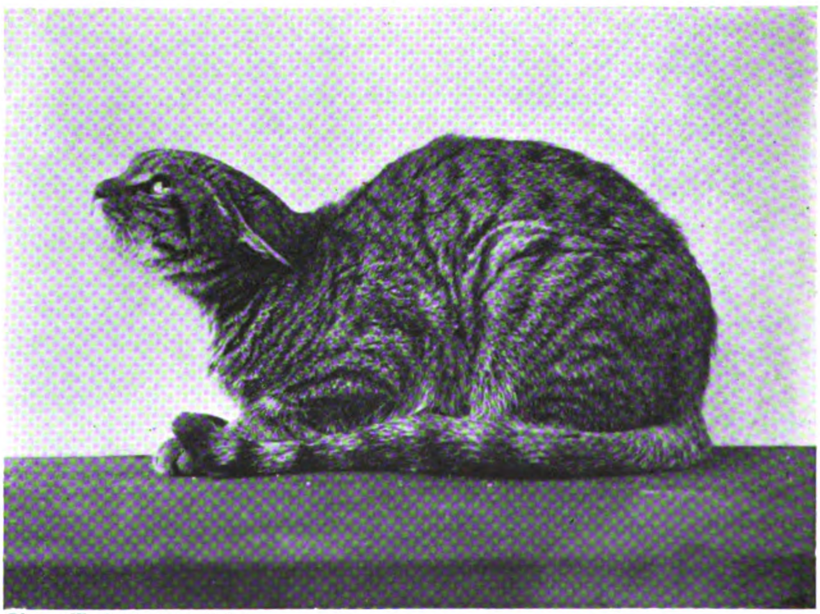


Photo: W. S. Berridge, F.Z.S.

EGYPTIAN OR FETTERED CAT (*Felis maniculata*).

This animal lives in Egypt and Abyssinia, and is sometimes called the Falb Cat. It is about the size of an average domestic cat, but with a longer tail. It is found in mummified form in ancient Egyptian monuments, and is regarded by many as the origin of the domestic cat of Europe.

Photo : Sport and General.

PERSIAN CAT.

On the widely accepted view that the common Domestic Cats are derived from the Egyptian *Felis maniculata*, it would be convenient to distinguish within the species a number of true-breeding varieties, such as Manx Cats without a tail, Chinese Cats with pendent ears, and Siamese Cats with blue eyes. Among these a place would be found for the beautiful long-haired Angoras and Persians.

Photo : C. Reid, Wishaw, N.B.

PERSIAN KITTENS.

A beautiful long-haired variety, related to the Angora Cat, probably a form of *Felis maniculata*, perhaps of Asiatic origin. It often attains to a large size, exaggerated by the long silky hair; but it is very markedly a house-cat and apt to be lazy.

as the leader of a pack that is now only a reminiscence. It is innately loyal, faithful, devoted. It loves and seeks to be loved. It hangs on word and look for approbation. It is lonely without its master; the lost dog is an epitome of misery. The dog is responsive, sensitive as a child, sympathetic in joy and sorrow, and asking for sympathy in return. The appeal in its eyes is irresistible.

But a cat is a bundle of contradictions. Affectionate, of course, but reserved, capricious, and detached. It has no enthusiasms. Fond of its master or mistress, but preferring the house to either of them. Dependent on man for thousands of years and with no end of polite ways; yet, when not pampered, how full of lurking wildness. Unlike the dog, which was domesticated for utilitarian reasons, and secondarily became a friend, the cat was adopted for æsthetic reasons, and it has remained a pet. No one can call a cat a friend. A dog becomes low-spirited if you do not assure it of your affection and approbation, but the cat will not turn a hair. It likes to be petted in moderation, and purrs most delightfully; but it can go without and be quite happy. As we said before, the cat is a conundrum.

Photo: F. W. Bond.

SIAMESE CAT.

A very beautiful domestic cat (*Felis maniculatus nobilis*), not often seen in Europe, highly prized in China and Japan. It is clever, affectionate, and a good mouser. The kittens are white with pink eyes, but they differ from pure albinos in assuming not a little colour later on. Thus the ears and feet are black, the face is very dark, the general colour is silver-grey, the eyes are blue.

Let us make a few notes on the cat's senses. Most cats are very quick to detect certain sounds that interest them but they cannot have much ear for music. Their serenading proves that. They are much excited by certain odours like valerian and cat-mint, but smell does not bulk so largely as in a dog's life. The dog's world is very markedly a smell-world, but the cat is in the main eye-minded. Notable is the variety of its acquired tastes; thus neither milk nor fish can have been available to the wild ancestors. We have seen a cat eating flowers; we have known one that was fond of cabbage, and another that loved toffee. We do not think that a cat will ever eat a starling, whose flesh is said to be peculiarly unpalatable, or a shrew, which has a repellent odoriferous gland along each side of its body. But the cat is a good sportsman, and may kill many a creature that it will not eat. The killing is often effected by a buffet on the head with the fore-paw, the high velocity making up for the relative lack of weight in the momentum.

A well-known feature is the cat's love at first sight for certain men. It sometimes exhibits a remarkable attachment to a stranger passing by or to a stray visitor to the house. Yet we do not think that cats are good judges of character. They are far too self-centred.

Of their intelligence there is no doubt. A dog is clever, but a cat is a sphinx. The brain

Photo: F. W. Bond.

JUNGLE CAT (*Felis chaus*).

This is the Common Wild Cat of India, also common in Africa, a great hunter, levying toll on game. The colour is yellowish-grey above inclining to reddish in some parts, and white below. There are few spots on the body, but there are stripes on the muzzle and limbs, and rings on the tail, especially in the young.

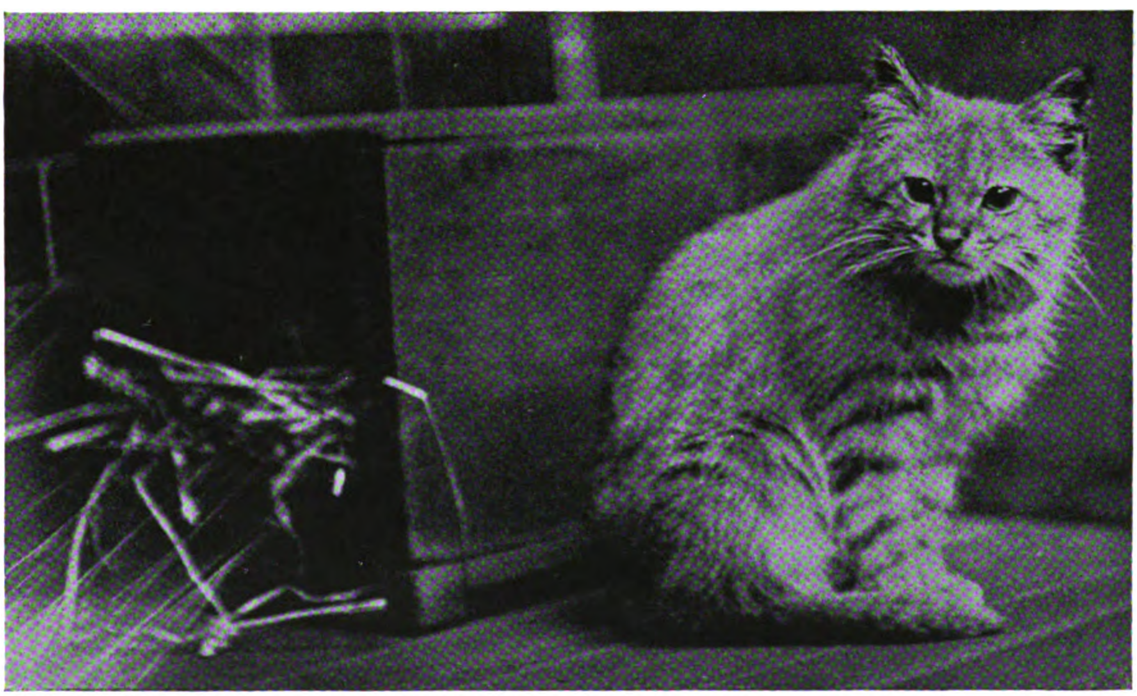


Photo: F. W. Bond.

PAMPAS CAT (*Felis pajeros*).

This South American Wild Cat is marked by its long hair and shortish tail. It is pale yellowish-grey in colour, with yellow or brown bars, running obliquely from the back and the flanks. It hunts the small mammals of the Pampas and does very little in the way of harm.

Photo: E. R. Gamage.

THE OCELOT OR TIGER-CAT (*Felis pardalis*).

Although in colouring the Ocelot of Central America is not unlike a small leopard, only its legs are spotted. The pale-yellow body-colour of its back and sides are marked with irregular stripes and bands of black, and these horizontal stripes distinguish it from all other cats. It is small, a good climber, and spends much of its time among the lower branches of trees.

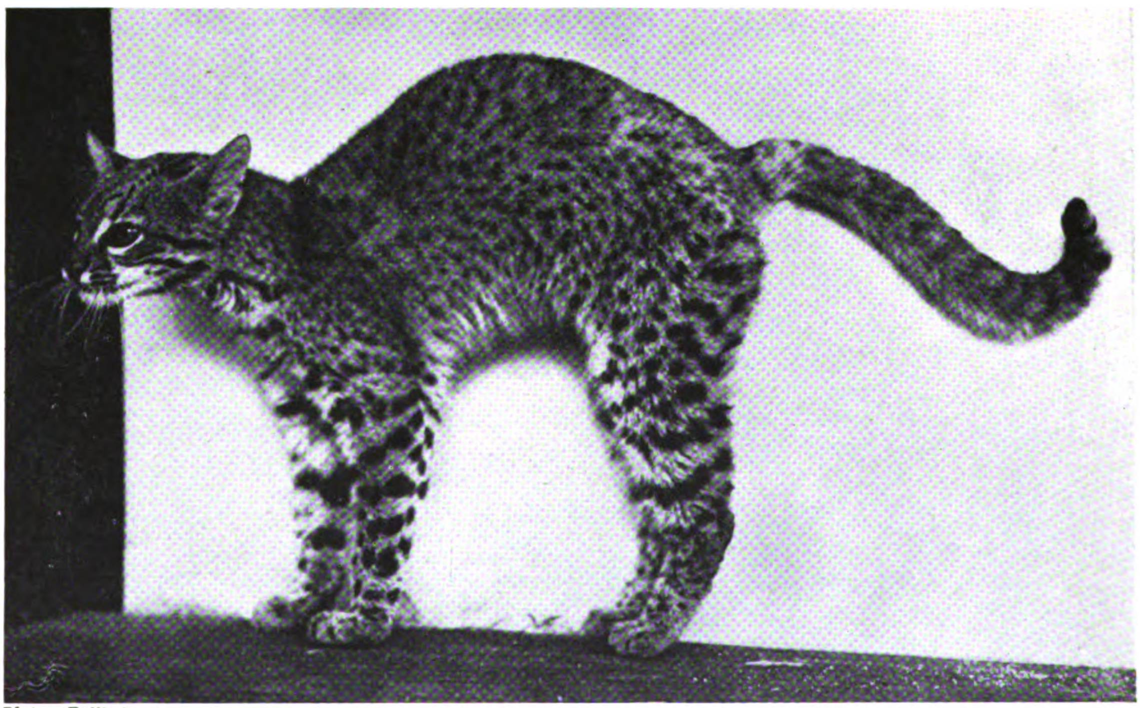


Photo: F. W. Bond.

THE SALT DESERT CAT (*Felis salinarum*).

A member of the Ocelot group of tiger cats, the Salt Desert Cat is found at high altitudes in the Argentine. It is somewhat larger in the body than the domestic cat, with slender legs, but it is smaller than the Ocelot, and the yellowish body-colour is marked with black spots.

is of a high order, though the cerebral hemispheres are not so much convoluted as one would expect—nothing like those of an organ-grinder's monkey, for instance. We have seen a cat put its paw into a narrow-necked vessel and sponge up the milk till none was left. At intervals it would look up at its mistress with an aggrieved air. A cat has been known to open the latch of a door by jumping up, or to work the knocker, or to ring a bell. A cat after buffeting its own likeness in a looking-glass kept gazing at it, but felt with its paw very carefully round the corner. It seemed surprised at finding nothing on the other side. A cat, whose fur had been accidentally wetted with paraffin from a lamp, took fire on the hearth. With her back in a blaze she dashed out of the open door, sped up the street for several yards, and plunged into a watering-trough. She had been in the way of seeing the cottage fire put out with water every night!

Cats have certain instincts, that is to say, inborn capacities for effective behaviour which do not require to be learned. Thus in its second month the kitten has its "mousing" instinct suddenly awakened by the sight of a mouse, and behaves in a perfectly definite way which ends in it seizing the mouse by the back of the neck. Then there is the play instinct, in the expression of which kittens serve an apprenticeship to the future business of life, and have also an opportunity for testing their individualities of behaviour. When an adult cat plays with a mouse it is relapsing, as various animals do, into juvenile playfulness, just as grown men do with their boys' miniature steam-engines.

Cats show considerable aptitude in forming associations. Thus Professor Thorndike used to sit near a cage where his cats were kept, and, having made sure that they were looking at him, would clap his hands and say, "I must feed these cats." After ten seconds he would take a piece of fish, go to the cage and hold it through the wire netting within reach of a particular cat, which immediately climbed up. After from thirty to sixty trials the cat learned to climb up when it heard the professor clap his hands and speak, without waiting for him to get the fish. This is a simple instance of association-forming, and it is a kind of mental operation that bulks largely in the life of cats.

Professor Thorndike's cats showed considerable cleverness in getting out of puzzle-boxes. The animals were hungry; the food was outside; the problem was to get at it. There were various ways of getting out, such as pulling a wire loop, raising a thumb-latch, or poking a paw out and clawing a string outside. When put into the box the cat tried all sorts of movements desperately, perhaps too hungry to be wise, and the right movement was hit upon by accident. "Only very gradually, as the experiment was repeated again and again, were the useless movements omitted, until finally the right one was performed at once."

Cats have good memories, for people and for places and for experiences. A very simple but pretty instance is given by Miss Washburn, in her "Animal Mind." A cat had shifted her kittens from an upper storey to the ground floor of a house. On coming into the house for the first time after this change of cradle she started upstairs to the old place, but stopped half-way up, turned and ran down to the new one.

After we have allowed for instincts, such as that which may lead a cat to mother a young rat, and for establishing associations, and for memory, we must admit that there is a delightful residue of activities which exhibit intelligence, a power of putting two and two together and making some sort of judgment or perceptual inference. But after we have granted intelligence, the cat still remains, in the domain of feeling, a mystery.

Another interesting attribute of the cat is homing. Put into a closed basket and taken in a railway carriage to some distance, the cat may find its way back. Its attraction for place seems sometimes stronger than its affection for people. Take a single well-documented case. A household migrated from Kirkcaldy to an Ayrshire village, taking their cat with them. The change did not please the cat, which was well advanced in years, and in a few days it was missing. In a short time a letter arrived from Kirkcaldy, stating that the cat had appeared at the old home. Now it is a far cry for a cat from Ayrshire to Fife, and we do not know how the journey was made. The possibility of the cat's taking observations on the outgoing journey was excluded, but we do not know whether the cat made many mistakes on its way back, whether it followed the railway

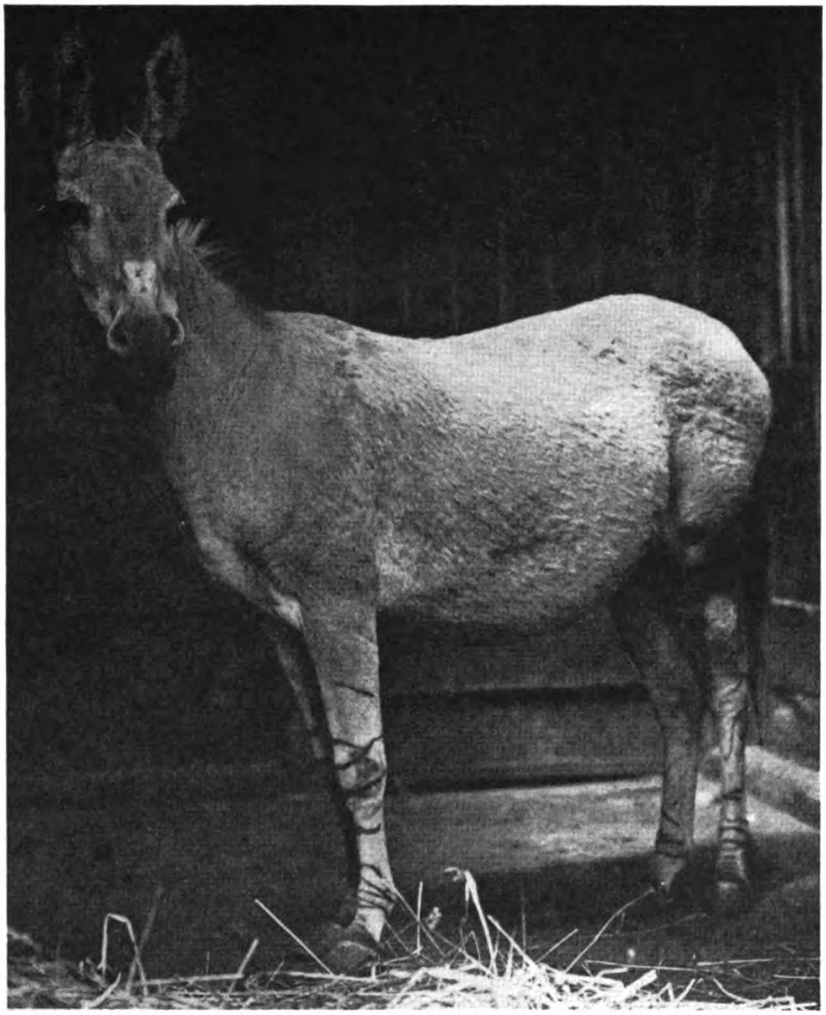


Photo: F. W. Bond.

SOMALI WILD ASS (*Equus somalicus*).

This African Wild Ass from Somaliland seems to be quite different from the Nubian Wild Ass (*Equus africanus*). It has a greyer colour, smaller ears, a longer and more flowing mane. There is no shoulder stripe and the dorsal stripe is faint; but, as the photograph shows, there are numerous cross stripes on the legs.

route or went across country, whether it got a lift or went the whole way on foot. It would have been interesting to have repeated the Kirkcaldy-Ayrshire journey to see if the cat would "home" again. The same kind of "homing" capacity is exhibited by various other animals, including sheep, which are certainly not clever; and it would be of scientific interest to devise some experiments which might throw light on the mysterious power.

To speak of the donkey as stupid is very wide of the mark. A donkey is much cleverer than a goose, and that is saying a good deal. But donkey and goose suffer from popular misunderstanding, both have brains of a high order.

The Donkey. There is general agreement that the domestic donkey is a direct descendant of the North African wild ass, but it must be remembered that there has also been domestication of other wild asses, like the onager of Assyria. What the donkey might always be, if properly cared for, may be inferred from what the wild ass still is—a creature of high spirits, alert senses, keen intelligence, and great beauty. Sir Samuel Baker writes: "Those who have seen donkeys in their civilised state have no conception of the beauty of the wild or original animal. It is the perfection of activity and courage, and has a high-bred tone in the deportment, a high-actioned step when it trots freely over the rocks and sand, with the speed of a horse when it gallops over the boundless desert."

One is reminded of the old lines:—

"Who has sent out the wild ass free?
Or who has loosed the bands of the wild ass?
Whose house I have made the wilderness,
And the barren lands his dwellings.
He scorneth the multitude of the city,
Neither regardeth he the crying of the driver.
The range of the mountains is his pasture;
And he searcheth after every green thing."

The reference in this Old Testament passage is probably to one of the Asiatic wild asses or onagers, which the Nineveh bas-reliefs prove to have been domesticated in Assyria by at least 600 B.C.

Of the kulan or onager of the Kirghiz steppes, Brehm tells us that it is "a proud, fascinating

creature, full of dignity, strength, and high spirits. He stares curiously at the horseman who approaches him ; and then, as if deriding the pursuer, trots off leisurely, playfully lashing his flanks with his tail. If the rider spurs his horse to full speed, the kulan takes to a gallop as easy as it is swift, which bears him like the wind over the steppes and soon carries him out of sight. But even when at full speed he now and then suddenly pulls himself up, halts for a moment, jerks round with his face to the pursuer, neighs, and then, turning, kicks his heels defiantly in the air and bounds off with the same ease as before." It is often said that the onagers of the steppes cannot be overtaken by horses, and that they are quite untamable ; but neither statement conforms with the facts.

Our picture of the wild ass is that of a very active, alert, high-spirited, hardy animal, able to thrive on Spartan fare. They are polygynists, and the males fight savagely with intruders and upstarts. The foals are playful and roguish, very trustful of man, and almost always easily tamed. The problem that arises is how such fine creatures have given origin to donkeys, often stunted, sluggish, and dull. The first part of the answer is that the domesticated degeneration is far from being a necessity. In countries where attention is paid to breeding there is a persistence of many of the excellent qualities of the wild ass. There are many handsome and lively breeds of donkeys ; and they hand on some of their good qualities to mules. But in many countries the ass is the poor man's horse, and this too often means that the owners have ceased to pay any attention to breeding. The degeneracy of the

Photo : C. Reid, Wishaw, N.B.

DOMESTIC DONKEY AND FOAL.

The origin of domestic animals is involved in great obscurity, and care must be taken to keep to cautious statements. Many authorities maintain that the domestic donkey had its origin in the Nubian Ass (*Equus tæniopus*), also called *E. africanus* and *E. asinus*. To this, others would add that domestic donkeys of fine breed were also derived from the Asiatic Onager (*Equus onager*).

Photo: H. M. Bell.

OORIAL SHEEP.

A large-horned, hardy sheep from the mountains of the Punjab, with the whole neck thickly bearded. It has a reddish-brown colour above, lighter to white below. The points of the large horns are directed inwards.

donkey is a diagram of what must happen without "good breeding" or eugenics. A third-rate donkey is a diagram of bad breeding!

The second part of the answer is that close confinement does not suit the ass, which is as much a child of the desert as is the Bedouin. They say that the donkey's frequent objection to cross a streamlet traversing a country road is due to mutiny on the part of its "Unconscious," which came into being when its ancestors were wild asses in the desert. More simply, the donkey's desert past lives on in its costermongering present.

The donkey is a creature of frugal tastes, and its owners sometimes take thoughtless advantage of this by feeding it inappropriately. This is depressing in itself, but it may have a deeper influence by disturbing the normal activity of the ductless glands, whose chemical messengers or hormones exert a regulating influence on the life of the body. This is just a guess, we admit; but there is certainly a suggestion of there being something wrong with the ductless glands in some of the very dwarfish and very depressed donkeys of poor localities—some of them, as Darwin noted, "not much larger than a Newfoundland dog." But, without any speculation, we may ascribe the degeneration of the donkey, when it occurs, partly to careless breeding, which affects the hereditary constitution, and partly to bad "nurture" (including food, stabling, grooming and treatment), which affects the individual, but may be re-impressed on each successive generation.

They say that the donkey's fondness for rolling in the dry dust is another re-awakening of an ancient desert memory, and whether this be sound or not, we must regard the domesticated animal as

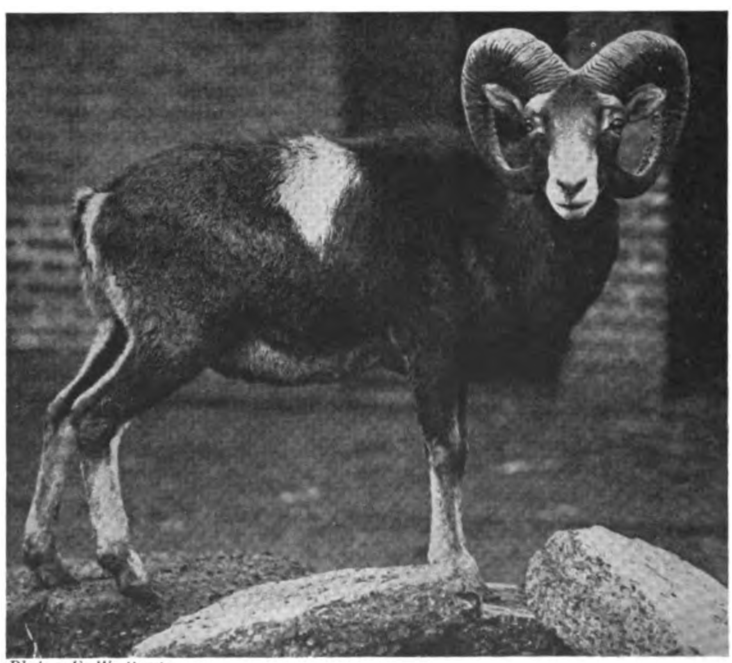


Photo: F. W. Bond.

MOUFLON (MALE) (*Ovis musimon*).

There are many kinds of Wild Sheep and some of them have a very restricted distribution, nowadays at least. Thus the short-tailed Mouflon, once with a wider range, frequents the hills of Corsica. It is brownish-grey, with some white about the face and elsewhere. The horns are confined to the males.

Photo: C. Reid, Wishaw, N.B.

SHEEP ON THE HIGHLANDS.

Sheep are in a general way distinguished from goats by their rather stouter build, their thick fleece, and the absence of beard. The horns, if present, are usually twisted, and occur in both sexes, though stronger in the rams. The playfulness and adventurousness of lambs in domesticated conditions may be interpreted as a juvenile survival of the primitive wildness.

BARBARY SHEEP (*Ovis tragelaphus*).

This is a handsome wild sheep confined to Northern Africa, sometimes called the Arui or Aoudad. It has comparatively smooth olive-coloured horns, which show a marked approach to the horns of goats. In some other ways the Barbary Sheep links on to the goat.

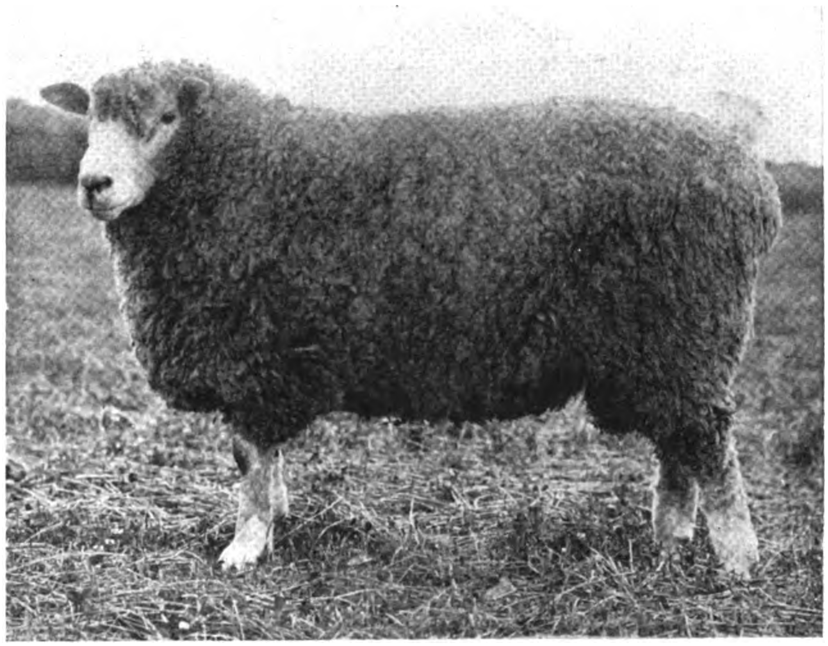
in some measure a spirit in prison. The wild ass is so singularly a child of freedom that man's *depression* of the donkey is something like a breach of faith. We do not say the domestication, but the depression, for there are many places where donkeys are well bred and well cared for, where they live long and cheerful lives. But we cannot help wondering sometimes whether the depressed donkey represents a naturally gay creature that has lost heart, and whether its apparent stupidity is not a self-protective device against man's lack of appreciation. We have read that when horses and donkeys are in great herds together on American ranches the larger species follows the lead of the smaller, and show an evident respect for its sagacity. From an animal with such a fine brain as a horse has, this is a great compliment!

We have not yet explained why a donkey is an ass, and not a small horse. But the asinine specific distinctions are familiar. We think of the tail with the tuft at the end, the dark stripe on the shoulders, the upright mane, and the absence of warts on the hind-legs. Then there is the length of the ear-trumpet of which Wordsworth spoke so characteristically, "and on the pivot of his skull he slowly moved his long left ear." It may also be noted that the blood crystals of an ass are different from those of a horse. But it is perhaps easier to understand what a difference between two species means when we hear the neigh and the bray. The bray is only intelligible when we think of it as a voice calling in the wilderness.

It is a great pleasure to watch the lambs at play in spring, and the sight raises many Natural History questions:—What is the meaning of this play? Why do the adventurous lambs become such stolid sheep? Where did these domesticated sheep come from? Let us take the last question first.

Sheep and Lambs.

The probability is that domestic sheep had a multiple origin from several kinds of wild sheep, including the mouflons of Cyprus, Corsica, and the East, the Urials of Turkestan, and the long-horned Argali of Tibet. Professor Cossar Ewart has shown that one of the most primitive sheep in Britain is that which occurs in Soay, a small island to the west of St. Kilda. It is a short-tailed small animal, the rams standing just about two feet at the shoulder, and the hornless ewes distinctly smaller. The ears are small, the limbs are slender, and the horns of the ram are large and curved. The point is that the Soay sheep is very like the wild mouflon of Cyprus. Another primitive form is the brown Loaghton of the Isle of Man, and there are others in the Faroe Islands, Shetland, and Iceland. It is interesting to find that on islands where pasture is scarce the primitive sheep will eat the seaweed



A LINCOLN RAM.

The male of the sheep is well-known for its strength, its combativeness, and its strongly developed sex. The bones of the skull are very strong and the crash between two rival rams often leaves neither any the worse. In all probability the original home of tame sheep was in the mountains of Asia.

on the shore, and will even go the length of feeding on dried fish.

The outstanding differences between domesticated and wild sheep are two: the former usually have wool and the latter have short tails. Wool is an exaggeration of the under-fur or under-hair, which becomes delicate and thick and tangled; the ordinary outer hair of the sheep is visible on the legs. The sheep's fleece corresponds to "sealskin," both consisting of the under-fur. The entanglement of the woolly hairs is often so extensive that great patches come off coherently, and then people go "wool-gathering" to good purpose. In the brown "murrid" (moor-red?) Shetland sheep, whose wool is knitted into deliciously soft shawls and "jumpers," the whole fleece is sometimes pulled off in a piece. What Neolithic man did was to breed from wild sheep that showed that they were changing in the direction of increased woolliness of the under-hair.

In all the wild sheep the tail is short, but it is far from being true that in all domesticated sheep it is long. There are various short-tailed breeds, and there is very marked reduction in some of the black-faced sheep. On the whole, however, there has been a tendency towards a lengthening of the tail in domesticated sheep, and this sometimes becomes so excessive that the tail touches the ground. This can be remedied by docking, but where the tail fattens greatly and is regarded as a luxury by the herdsmen, it may have to be provided with a little wheeled vehicle like a child's toy-cart. In this cart the sheep trundles its fat tail behind it—a good illustration of the queer things that may happen under man's protection. Nature would soon curtail an absurdity of this sort.

Our second question was about the sheep's sheepishness. Why is the sheep so stupid? Why has its brain gone badly back since it came into the hands of man? The reasons are not far to

Photo: C. Reid, Wishaw, N.B.

GOAT AND KIDS.

The general view is that the Persian Wild Goat (*Capra* or *Hircus ægagrus*), whose stomach secretion produces the "bezoar stone," is one of the species, and probably the principal species, from which domesticated goats have been derived.

Photo: Underwood Press Service.

GOATS ON THE ALPS, SWITZERLAND.

Goats differ from sheep in their spare build, their backward-arched horns not spirally twisted, their beard, and the rank smell of the males. The European breeds are regarded by many authorities as derived from the Eastern Bezoar Goat (*Capra* or *Hircus ægagrus*). Somewhat chamois-like forms are common on the Alps, but they are not wild in the true sense.

seek. In the first place, man sifted out, that is to say, *ate* the adventurous, experimental, independent sheep, which were troublesome members of his flock. In the second place, man made things too easy for his sheep, giving them a sheltered life, yet not admitting them into any enlivening partnership like that established with dogs and with horses. No doubt the Himalayan Hunia sheep carries salt and borax across the passes; no doubt the Punjab Barwal sheep becomes a prize-fighter; but the ordinary domesticated sheep lives a stolid life and is stupid. It does not live dangerously enough. To put the matter in a nutshell, sheep miss wolves badly; and man is to blame.

As Mr. P. G. Hamerton remarks in his "Chapters on Animals," sheep belie the promise of their youth. "If you had never seen a sheep, and a young lamb were presented to you for the first time, would you not augur well for the future of an animal so charmingly merry and playful? You would say, 'Here is a creature born to learn all things rapidly, since at his second sunrise he is already so much at home upon the earth.' But every day the lambs become less charming and less beautiful, and at last, when fully fleeced they present scarcely more form than a hedgehog—and they eventually show a lamentable poverty of wit and invention."

This contrast between the lamb and the sheep is very striking, and has not received the attention it deserves. Although lambs have not the brains of a kitten, they are sprightly, experimental, and playful. They have three or four different games, and we have seen traces of a sense of humour. But they soon begin to relapse. They have betrayed, for a brief space,

the wild past that lives on in their present; they have shown for a moment the sheep's true self; but soon they give way to a growing sheepishness. The reason is that they are victims of a terrible process of "repression"—an automatic sinking down of their lively promptings and emotions into the depths of the "Unconscious."

It is plain that the chief repressive forces must be found in the profound respectability and stolidity of their parents. They find themselves in an ovine world that is intolerant of fun and originality, experiment and adventure; and there is no escape. The stultifying works in a vicious circle, for the more readily the promiseful young creatures submit or acquiesce, the more repressive will they have become when they have lambs of their own!

The Pig and the Boar.

When we compare the domesticated pig with its ancestor the wild boar, we see how apt man is to make a muddle of things from the point of view of beauty. For the wild boar is a handsome shaggy animal, with wide-awake eyes, rapid movements, and great courage, whereas the pig is obese and out of proportion, disagreeably naked-looking, with eyes half-hidden in fat, legs too weak for the body, and a timid disposition. Well might the pig have said: Save me from my friends. But we cannot undo the spoiling which our Neolithic ancestors began. Moreover, most people prefer bacon to beauty.

"Pigs are a race unjustly calumniated," said Dr. Johnson, and never were truer words spoken. A greedy gluttonous creature! But who would not be greedy if descended from ancestors that could not count on regular meals and had to make the most of them when they were forthcoming? Truffles cannot be stored. A dirty creature! But who would not be dirty if condemned to pig it in a pigsty? Those that are kept in the open on the new method are not dirty, though they undoubtedly enjoy a mud-bath. The phrase "wallowing in the mire" betrays a prejudiced mind, a jaundiced eye. But the corpulence of the animal! Yet is this not man's fault, since he gives over-abundant and easily-obtained food to the descendant of boars that had to lay up fat for the unfriendly winter? And he selects with prejudiced eugenics in favour of the best fatteners. As Dr. Johnson said: "Pig has, it seems, not been wanting to man, but man to pig." Justly indeed may the pig turn on man the domesticator and accuse him, saying: Where are the ears of my forefathers that used to be long and shapely, as the Japanese have left them in the breed called "Masked"? Where are my ancestors' stout legs, able to outrun a cantering horse? Where are the pleasing lines that spoke of strenuous work, and where the strong tusks that spoke of battle? The fact is that man has made rather a fool of the pig, converting a solitary animal to gregariousness, and turning a creature of the darkness into a lover of the garish day.

The origins of most of our domesticated animals are very difficult to trace, and we would not be dogmatic about the hog. But the probability is that it arose at least twice in Europe, and a third time in Asia. One of the European domestications began in the region of the Baltic, and its source was the North European Wild Boar (*Sus scrofa*). The second domestication began somewhere in the Mediterranean region, and its source was a wild form intermediate between the Northern Wild Boar (*Sus scrofa*) and the Asiatic Boar (*Sus vittatus*). The latter formed the material for the Oriental domestication, perhaps the oldest, and its introduction into Europe had a great influence on the domesticated forms of Northern Wild Boar origin.

An interesting example of the past living on in the present is the occasional appearance of colour-stripes on young pigs, which is of general occurrence in the wild state. Another, but very different, echo of the past is heard in such place-names as Boar-stall, reminding us that the wild boar was at home in England till about the end of the fifteenth century.

P. G. Hamerton, in his delightful "Chapters on Animals," is unusually appreciative of the mental aspect of pigs. "The animal, though obstinate and self-willed, is really not stupid, and is capable of the warmest attachment, and of great fidelity to those he loves." It is much to be regretted that Saint Anthony did not leave any impressions of the pig, who was his chosen friend and companion. Few men have had such a fine opportunity, and most of the records of the intelligence of pigs are very casual. Romanes tells of a year-old sow that shook a

Photo: F. W. Bond.

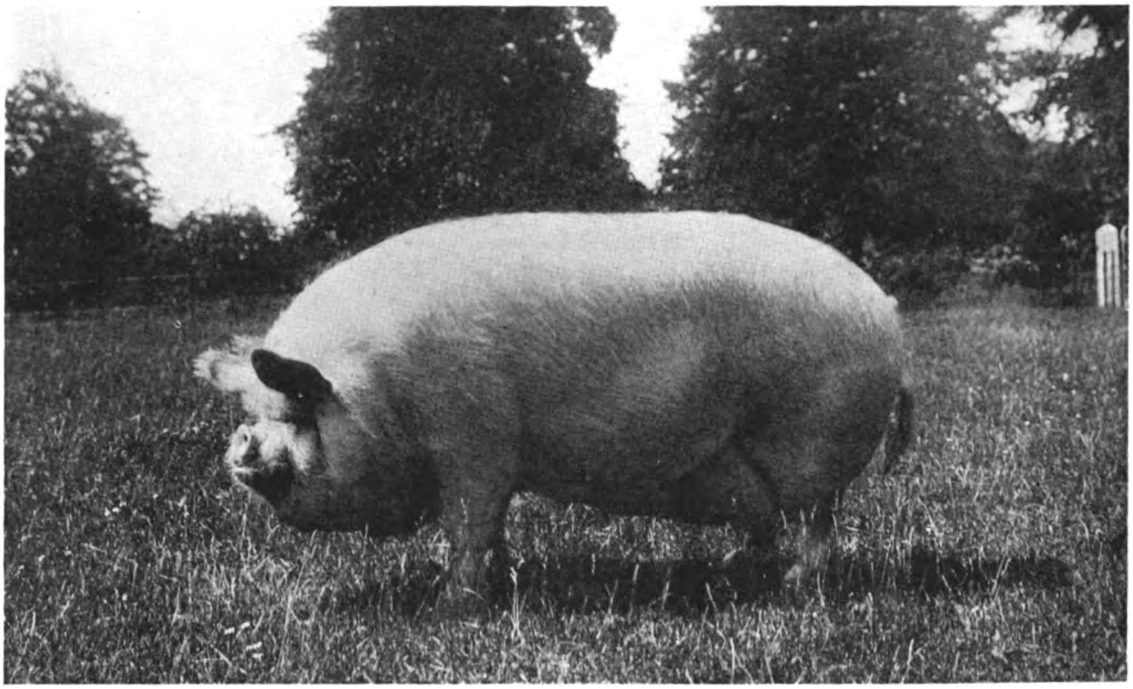
RED RIVER HOG (*Potamochœrus penicillatus*).

This wild pig is found in West Africa and in Madagascar, but it is not far apart from the true pigs of the genus Sus. Many of the kinds show a fine ruddy colour in their hairs and bristles. The long slender ears are continued into a waving pencil of hairs, to which the name penicillatus refers.

Photo: E. R. Gamage.

PECCARY (AMERICAN WILD HOG).

This small pig is represented from Arkansas and Texas southwards to Paraguay and Patagonia. It gets various technical names, Dicotyles, Peccari, and Tayasu. It is fondest of brushy upland jungles, and is almost omnivorous. It lives gregariously and hunts at night. There is a musk-gland on the top of the hind-quarters, hence the common name musk-hog.



ENGLISH WHITE SOW.

Many of the domesticated breeds of pig have diverged greatly from the wild type. Thus they show a decrease in the length of the legs, an increase in rotundity and fatness of body, and an improvement in the delicacy of the flesh. The sow is very prolific, often with two litters in a year, with four to eight in a litter, occasionally with a dozen.

young apple tree in the orchard and listened for the thud when the fruit fell. " After they were all down and eaten she shook the tree and listened, but as there was no more to fall she went away." This Eve was no doubt a far cry from Newton and the apple, but the story shows that the pig is not without the root of the matter. There are stories of both tame and wild swine combining successfully against a wolf, and this is more interesting than the records of " performing pigs," where there is little more than forcing the animal to establish certain associations. We cannot endure this adding of insult to injury. Pigs are clever at opening latches and the like, and the young ones are playful, which is always a good sign. As Dr. Johnson said, we do not allow time for their education.

The Ancient Britons worshipped the boar, but " pig " is the last word of reproach. Mr. Hamerton notices that even the peasantry in France reserve the name for supreme occasions of abuse, and to keep the barb sharp will use some quite different name for the animal itself. They have their *patois* words, of course, but " when they speak pure French they use a periphrasis of quite remarkable elegance, hitting upon the only peculiarity about a pig which reminds one of genteel society." They call him *un habille-de-soie*, " a dressed in silk," the allusion being to the beautiful white bristles, shining in the sun. But why is the pig so much a beast of reproach ? Not because it is not beautiful, not because it is dirty, not because it is omnivorous and insatiable, not because it is a focus of parasites. What then ? We think the right answer must be one that we found in a book on Domestication by Dr. Antonius, who points out that the pig is the mark of the " settler " as contrasted with the " nomad." Pigs cannot be moved about like sheep and cattle, and the old shepherds and hunters focussed their contempt for the " settlers " on their most characteristic animal—the pig. Religious, hygienic and æsthetic considerations were secondary : contempt for settling down was primary.

Another of man's dependants, the Common Goose, has suffered from misunderstanding. Everyone appreciates its good qualities when it is dead, but few have realised what a fine bird

it is when alive. There is bad Natural History in such a phrase as "the silly goose," for the creature is alert and clever. Like some of ourselves, the goose is much wiser than it looks. Their "cackling," as we contemptuously call their conversation, is oftenest an expression of a sociable disposition—they wish to pass the time of day. Or else it expresses, often with admirable alertness, *a detection of the stranger*: "Who is this that comes riding sae boldly through oor town?"

The Goose.

Where did this domestic bird come from? Some say it is older than all poultry. We know that the Greeks of Homer's time had flocks of tame geese, and that Penelope fed them in the precincts of the palace. Of the origin of the Domestic Goose there is no doubt: it is a scion of the wild Grey Goose, a migratory bird of Central and Northern Europe that flies to the south and east on the approach of winter, and returns in March. There cannot have been any difficulty in annexing the goose to man's stock, for, unlike most domestications, which remain secrets of the remote past, the domestication of the Grey Goose can be achieved to-day.

What is particularly interesting is that the Grey Goose, under man's shield, has lost so little. The Domestic Goose is an easy-going, placid, pliable creature, inclined to be stout and heavy-footed, and with greatly reduced power of flight—in part, no doubt, an individual consequence of lack of aerial exercise. *But it has remained very much itself*, and while it is what one might call a tranquil conservative type, it has retained many of its wild characteristics, such as quick wits.

There is very little in the Domestic Goose corresponding to the multitude of varieties familiar among pigeons and hens. One reason for this is simply that the goose is an organically conservative type. The other reason is that the

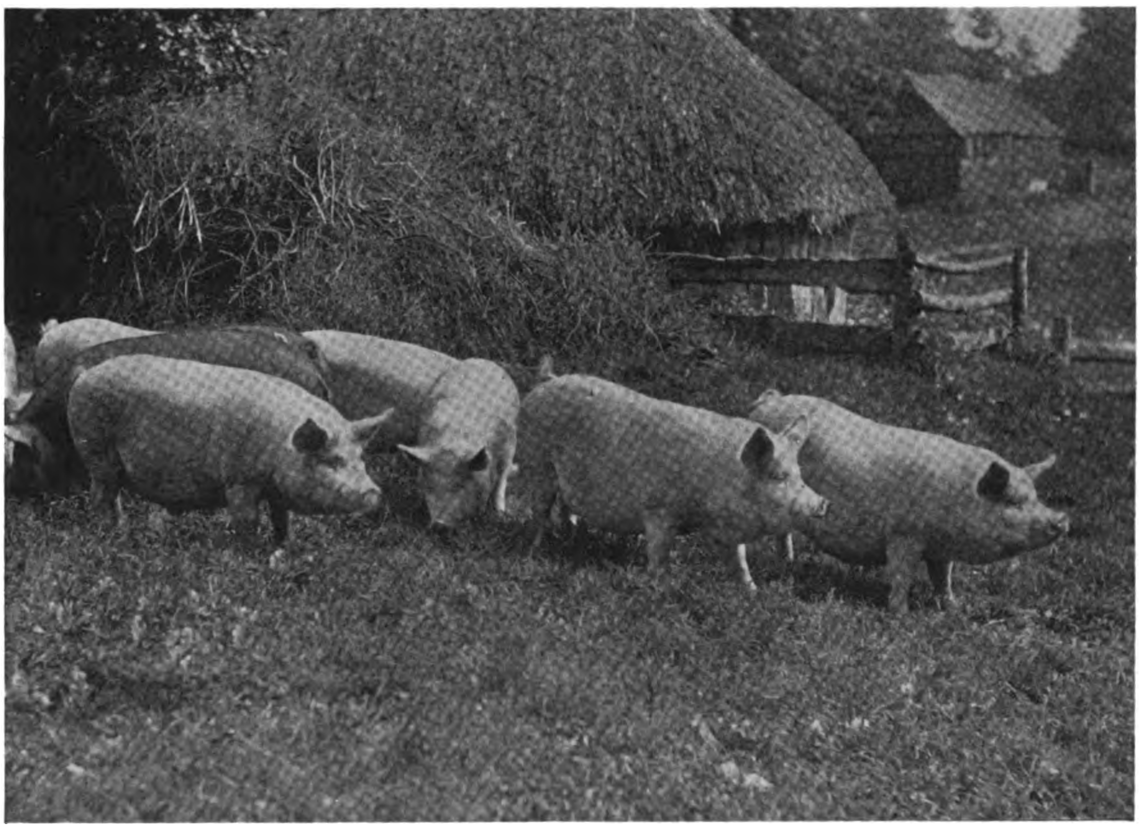


Photo: C. Reid, Wishaw, N.B.

DOMESTIC PIGS.

According to many authorities the main race of European domesticated pig (*Sus scrofa domestica*) has been derived from the Wild Boar species (*Sus scrofa*), which lingered in Britain till the sixteenth century. But it is not inconsistent with this view to hold that other wild pigs, especially the Asiatic *Sus vittatus*, have also given rise to domesticated breeds, and may have been crossed with *Sus scrofa* or its derivatives.

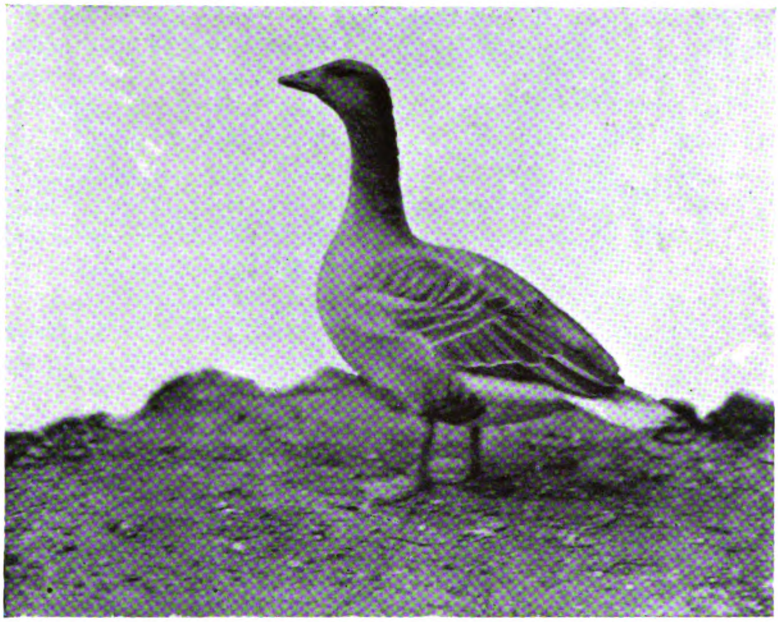


Photo: W. S. Berridge, F.Z.S.

GREY LAG GOOSE (*Anser anser*).

This is the only kind of goose that nests in Britain, the others being winter visitors. Its nesting-places are now confined to the North of Scotland and some Hebridean islands. According to some, the Grey Lag owes its name to the fact that it lagged behind while others migrated.

goose was from the practical man's point of view *so nearly perfect* that divergent varieties were rarely welcome. So they were not taken care of. Not that varieties are entirely absent, for there is the pure white Emden Goose, with blue eyes, orange feet, and yellowish-red bill—a very beautiful bird; and there is the Sebastopol Goose—a small variety with what one might call curly feathers. The Canada Goose, sometimes domesticated in Britain, belongs to a different genus altogether. Similarly, the tame goose often depicted on ancient Egyptian monuments is another quite different kind, but also of great beauty and value. For ages it was domesticated in large herds, as may be seen in a British Museum picture from Thebes, but for some reason or other it has been allowed in Africa to relapse into a quite wild bird. As such it extends from Egypt to the Cape. It is sometimes domesticated in Britain.

As we have said, the wild ancestor of our Domestic Goose is the Grey Lag, which still breeds in the North of Scotland. It does harm in cornfields, for it has a big appetite, but it is a very attractive bird. It is monogamous in the strictest sense, and the gander guards his children. There is a good deal of education of the goslings, which are taken to the water a few hours after hatching. There is no posting of sentinels, we are assured, but there is extraordinary wariness. The only infirmity is a certain liability to get nervous towards the ordeal of moulting time, when the loss of feathers involves a riskful period of flightlessness. It is then that the geese, leading their young ones, will march through fields and woods to some new home,

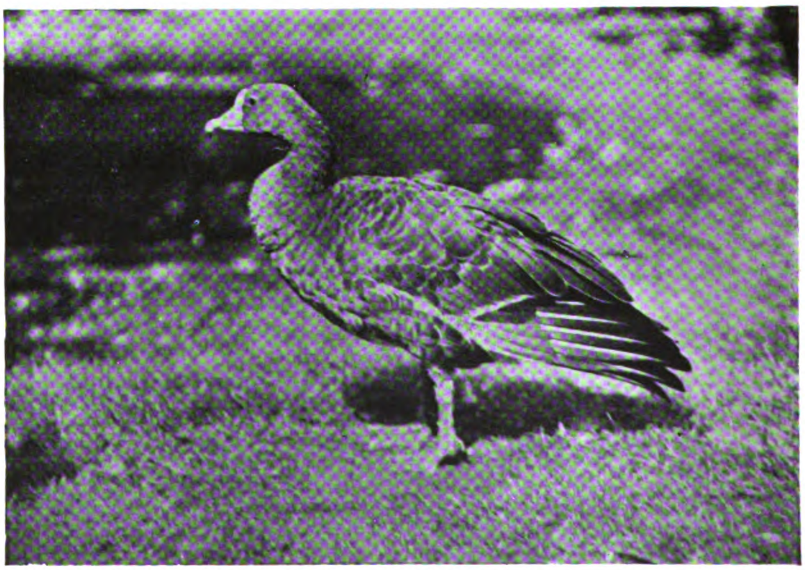


Photo: W. S. Berridge, F.Z.S.

WHITE-FRONTED GOOSE (*Anser albifrons*).

This is a common winter visitor to Britain, that nests farther to the North. It is smaller than the Grey Lag, and owes its name to a broad white band at the base of the bill. It is sometimes called the Laughing Goose because of its loud challenging note.

and when they get there will march back again, often losing some of their charges by the way. Is it to this instinctive searching for a safe place that the nursery rhyme refers:

"Goosie, Goosie, Gander,
Where shall we *wander*"?

The Grey Lag is the only wild goose that breeds in Great Britain, but others come as regular winter visitors—the Pink-footed, the Bean, the White-fronted, the Bernicle, and, commonest of all, the Brent Goose, which is sometimes seen in extraordinary numbers on the East Coast. These all leave us early in the year to make their nests in the Far North; the Grey Goose *lags* behind, and so, a great etymologist tells us, it is called the Lag-goose.

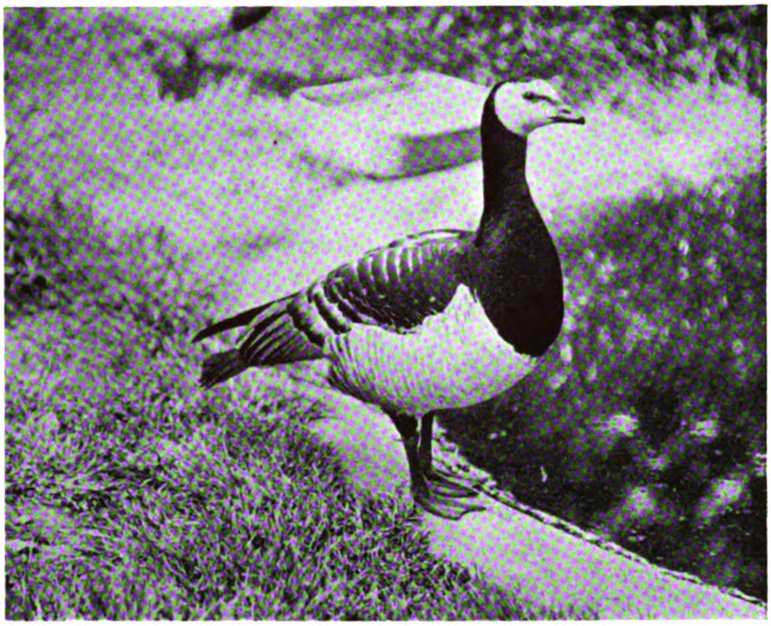


Photo: W. S. Berridge, F.Z.S.

BERNICLE GOOSE (*Branta leucopsis*).

This goose nests in Arctic Regions but often visits Scotland in winter. It feeds mostly by night and mainly on vegetable food, though it will also eat molluscs and crustaceans. Its name refers to the old confused idea that ship-barnacles gave rise to geese.

The true inwardness of the goose was appreciated by the late Mr. W. H. Hudson. He speaks of its "lofty spirit," still proud and independent in spite of domestication; of the "ancient instinct of watchfulness," excelling that of a dog; and of its affection—sometimes chivalrous. He has left a picture, which one does not readily forget, of two South American geese at the migrating time. "The female was walking steadily on in a southerly direction, while the male, greatly excited, and calling loudly from time to time, walked at a distance ahead, and constantly turned back to see and call to his mate, and at intervals of a few minutes he would rise up and fly, screaming, to a distance of some hundreds of yards; then finding that he had not been followed, he would return and alight at a distance of forty or fifty yards in advance of the other bird, and begin walking on as before. The

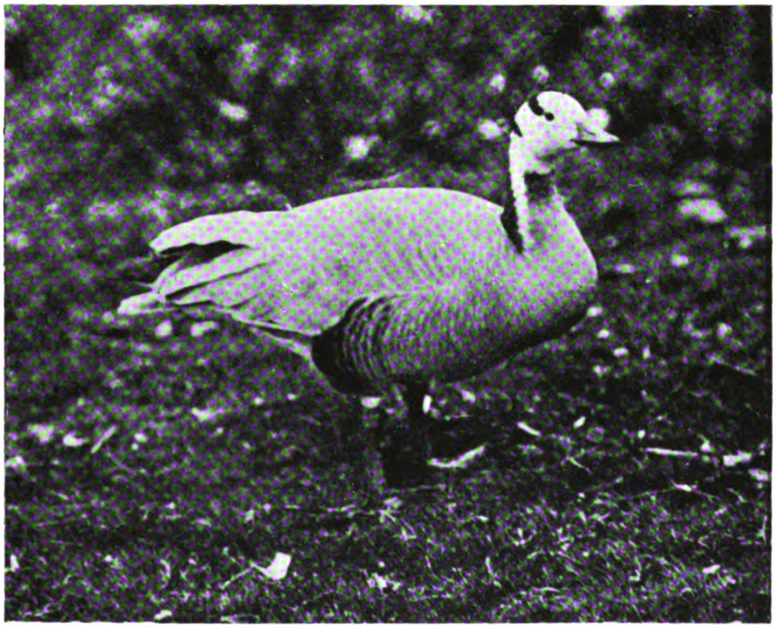


Photo: H. M. Bell.

BAR-HEADED GOOSE (*Anser indicus*).

A day-feeding, vegetarian "Grey Goose," at home in Central Asia and North India, occasionally kept in Britain on ornamental ponds, and sometimes escaping. It owes its name to the presence of two black crescents on the back of the white head.

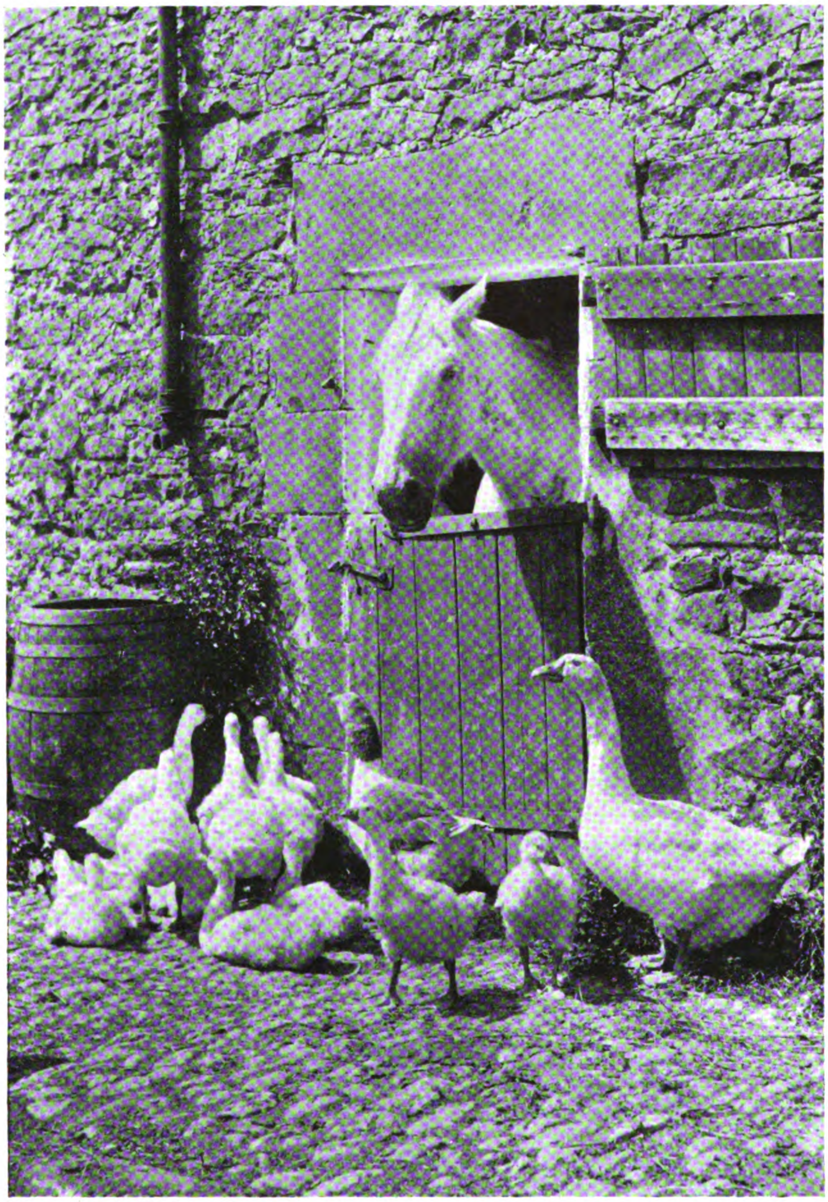


Photo: C. Reid, Wishaw, N.B.

DOMESTIC GEESE (*Anser cinereus* or *A. domesticus*).

A good example of conservatism in constitution, for the tame forms are very like the wild. Young wild geese are readily tamed, but do not lose their migratory impulse. A case is known of a wild goose returning to the farm where it had been reared.

female had one wing broken, and, unable to fly, had set out on her long journey to the Magellanic Islands on her feet; and her mate, though called to by that imperious imperative voice in his breast, yet would not forsake her; but flying a little distance to show her the way, and returning again and again, and calling to her with his wildest and most piercing cries, urged her still to spread her wings and fly with him to their distant home."

One agrees with those who insist that the wild geese say something better than "*honk, honk,*" as they make their way north in spring; but what is it that they say? As Miss Violet Jacob writes in her "Sons of Angus":

"And far abune the Angus straths
I saw the wild geese flee,
A lang, lang skein o' beatin' wings,
With their heads toward the sea,
And aye their cryin' voices trailed
Ahint them in the air. . .
O Wind, hae mercy, haud yer whist,
For I daurna listen mair."

The Robin

As an instance of a half-sentimental relation between man and certain living creatures, we wish to take the robin redbreast, most universally liked of birds. In the wintry season especially they are full of friendliness. During the summer they are a good deal preoccupied with family affairs, but in winter they seem rather at a loose end and inclined to be sociable with mankind. At this time they seem to live mostly as solitaries, an adaptation probably to the difficulty of finding food. For it is easy to understand that one robin may thrive where two would starve—especially when it is kept in mind that they are mainly dependent for food on insects and other small animals. They may utilise berries and occasionally seeds—and crumbs,

of course—but in the main they depend on animal food.

There was one with us the other day who was delighted with the parings of the unfried breakfast ham. So it is probably in part a cupboard love that brings the redbreast so much about the house. He appears everywhere in our case—in the kitchen, in the dining-room, in the bedrooms—always jaunty and cheerful, always self-possessed and hungry. We suspect it is the same fellow all the time, for we never see two ; and besides, it is well known that the robin has a very strong belief in the rights of private property. In other words, there is a strong territorial sense. " This is my preserve," he says. " Let intruders look out." But the tameness is extraordinary—he is not abashed by our conversation, and he is not much concerned at our movements.

We had to catch a visitor robin the other day that had got into difficulties when the blind was drawn down, but he remained quite peacefully in our hand, and his heart was not going pit-a-pat as the heart of an ordinary bird does in similar circumstances. What we should like to know is whether this confidence is simply a matter of temperament, or whether there has grown up among robins something like a tradition to the effect that man is a harmless creature. For no normal man would hurt a robin.

Often in the winter we hear a robin singing in the garden, evidently enjoying a glint of sunshine, and the bird is well known as one of those that sing outside the breeding-season—all the year round, indeed, except at the moulting-time, that occurs towards the end of July. What in most birds is restricted to the time of courting and mating has here overflowed, and saturated the whole life with joy. Another interesting point is that the female sings like the male, though

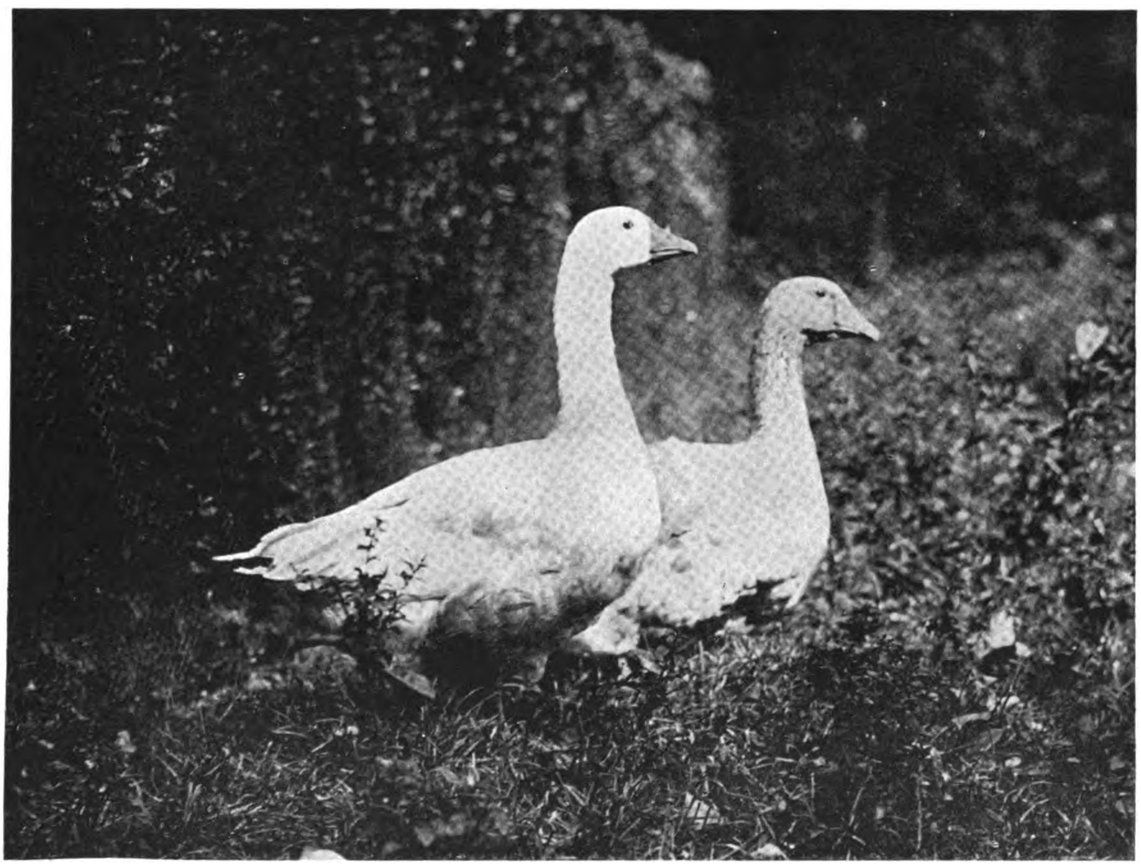


Photo : F. W. Bond.

GOOSE AND GANDER.

Domesticated forms of the Grey Lag Goose (*Anser anser* or *cinereus*). Compared with the wild forms they are heavier in build, lighter in colour, with reduced power of flight, and with shorter tail. According to Darwin, the fertility has increased under domestic conditions.

perhaps less ardently. For ourselves, we may as well confess that we cannot tell a cock-robin from a hen bird, except when we see the two together at the courting-time, when we conclude that the male is the one with the brighter breast and the more strenuous display.

The song has not a great range, but it is good hearing, and there is much more variety in it than one is at first inclined to think. John Burroughs wrote :—

> "His song is peculiar, jerky, and spasmodic, but abounds in the purest and most piercing notes to be heard—piercing from their smoothness, intensity, and fullness of articulation ; rapid and crowded at one moment, as if some barrier had suddenly given way, then as suddenly pausing, and scintillating at intervals, bright, tapering shafts of sound. It stops and hesitates, and blurts out its notes like a stammerer ; but when they do come they are marvellously clear and pure."

We did not get so much as all this out of the redbreast's winter song ; but we see the force of a comparison John Burroughs uses, that some of the redbreast's sounds are like those you hear when green hickory branches are thrown into a fierce blaze. Very familiar even in winter is the danger-signal, which sounds like "tik," by which the robin in one territory passes on to his neighbour the news that the big, slowly-moving, awkwardly crumb-scattering creature is on the prowl again. Our impression is that three "tiks" is the robin's way of spelling cat.

Cock-robin is an amorous bird, but he likes a quiet place for his courting. He raises his bill to the sky, cocks up his tail till it points almost forwards, puffs out his red breast, and sways from side to side before his desired mate. She stares

Photo : M. H. Crawford.

THE ORCHARD ROBIN LOOKING FOR CATERPILLARS.

The Redbreast (*Erithacus rubecula*) is represented by several forms, which differ slightly in colour. The diet varies considerably, from worms to insect larvæ, from flying insects to spiders, from soft berries to seeds. Everyone knows how they welcome breadcrumbs and the like in winter.

at him out of her big black eyes. In a more matter-of-fact mood, he sometimes presents her with a particularly plump spider or juicy caterpillar; and it is interesting that long after these goings on are over he brings her food when she is brooding. Not that he is unwilling to do his share of that. Both parents unite their energies in providing insect-food for the young ones.

The rather bulky nest of withered leaves, grasses, moss, often with hair and feathers to the interior, is to the credit of the mother-bird; and she often builds it in a place where there is some shelter This accounts for nesting in old kettles and other queer places such as the unlit lamp of the platform of a Highland railway station. The newly-hatched young ones cannot be called beautiful — big-headed, blind, helpless and flabby. "Ugly," as George Meredith said, "is only half-way to a thing," and the newly-hatched robin is not half-finished. Quickly, however, it puts on strength and grace, and becomes unsurpassable. There may be two or three broods in a summer.

Photo: M. H. Crawford.

HEN ROBIN ON NEST.

There is great variety in the site which the robin is willing to utilise for a nest, not merely holes in walls, banks, and trees, but a flower-pot, an old lamp, a scarecrow. But the robin is not aware how strange his choice is in man's eyes.

The redbreast or robin is held in universal regard, and there are several reasons for this. Its orange-red or tawny-red breast is very pleasing; there is a charm in its intelligent eye; there is something winning in its "bobs and flicks and jerks"; there is a suggestion of efficiency in its whole behaviour; and its song is a delight. There is probably something, too, in the fact that the redbreast does not desert us in winter; for although there are partial migrations, and although bands of the Continental variety pass over part of Britain as birds of passage in spring and autumn, the redbreast is a resident bird and sometimes keeps to one place all the year round. But the probability is that the redbreast has especially won man's heart by its confident trust in him.

We take the sparrow as another example of those creatures that hang on to man, so to speak. We should like sparrows better if

there were not so many of them. Their chirping and twittering is cheerful; they show admirable alertness in rising at the last moment from under the horse's feet; they are good parents; and the natural man enjoys the zest with which the cocks hurry to share in any "scrap." "Is this a private foight, or may a gintleman join in?" and they do not wait for

Sparrows.

Photo: S. Crook.

ROBIN IN SNOW.

The robin is a cheerful bird and sings in winter as well as in summer. Its song is compared by some to that of the nightingale, and some experts maintain that it is not confined to the males, as is usual. In winter at least it is claimed that the female robins sing.

an answer. Soon there is a little throng, all pecking and swearing and tumbling about with the utmost recklessness. But it is only a gust; in a few minutes they have forgotten all about it, and no one seems a bit the worse.

No doubt the cock-sparrow is a handsome fellow, and his mate, though plainer, is worthy of him. In summer the male is distinguished by ash-grey on the head and rump, and a deep black gorget contrasted with a white cheek-patch and a bluish-black bill. In winter the bill is brown, the white is yellowish, the black and grey have dulled into brown. In short, the cock's plumage in winter is nearer that of the female and the young bird. The tide of maleness is less strong in the cold season. The hen-sparrow has a brown bill and a conspicuous streak of buff behind the eye; she has no black gorget, no white cheek-patch, no ash-grey, and the colour of her mantle and wings is brown instead of mahogany red. We have cited these details because they afford a familiar instance of the puzzle of the often marked contrast of male and female (sex-dimorphism), and also because it is ridiculously careless to speak of a cock-sparrow as "a little brown bird." There is a good instance of individuality in the contrast between the House-Sparrow, of which we have been speaking, and the nearly related Tree-Sparrow, where the colour scheme is quite different. There is also a good instance of our ignorance in our ability to give any reason why the sexes in the Tree-Sparrow should be practically alike, whereas there is marked contrast in its cousin. An interesting little detail is the rubbing away of the light tips of the House-Sparrow's throat feathers in spring, which has the effect of giving prominence to the dark colour of the deeper portions.

The House Sparrow is a very successful bird, distributed all over Europe, represented by races of the same species in North Africa, West Asia, and India, and introduced into North

Specially drawn for this work by Roland Green, F.Z.S.

THE ROBIN.

The Robin or Redbreast (*Erithacus rubecula*), one of the most attractive of birds, beautiful in form and colouring, dainty and engaging in its ways, a fine songster, a high-spirited pugnacious creature, a careful parent. The sexes are alike. There is a narrow blue-grey margin between the olive-brown of the back and the red breast.

America, Australia, and New Zealand. Its success may be explained by its gregariousness, its long bill of fare, its plasticity as regards sites and materials for the nest, its prolific multiplication—often with three broods in the year—and its insistence on linking itself to man. But to these must be added a temperamental quality of pertinacity and aggressiveness, which may be illustrated by the way in which it sometimes ousts another bird, such as a House Martin, and occupies its nest. An interesting point about the sparrow's nest is that it is built with a dome when in the open, but the cover is dispensed with when the nature of the site makes it unnecessary. In the Tree Sparrow also a dome is occasionally constructed. This is noteworthy because sparrows are finches, and no other British finches build domed nests. In calling the sparrow a finch we may be pardoned for saying that the hedge-sparrow is not a sparrow or anywhere near it.

What about family affairs? The cock-sparrow has not the resplendent dress of the goldfinch or the chaffinch, and he has certainly not got the lintie's song, but he has his courtship on-goings like the rest of the finches. He hops and poses before his desired mate, who often rewards him with a severe pecking. He has a quaint way of drooping his wings and throwing back his head as if to show off his brilliant black gorget. Edmund Selous says that an attempt to look sentimental seems to struggle with his habitual self-satisfaction, but this sounds like reading the man into the bird. Two cocks sometimes court the same hen at the same time, and that of course means a fight. But when everything is settled the sparrow is monogamous. The hen broods very devotedly; according to some observers, the cock occasionally takes a turn. Both

Photo: Langford.

NEST AND EGGS OF ROBIN.

The large nest is made of withered leaves, dry grass, and moss, and daintily lined with hair and feathers. Five or six eggs are laid, white in general colour with spots or blotches of red. They are often laid in March, or it may be earlier in the year.

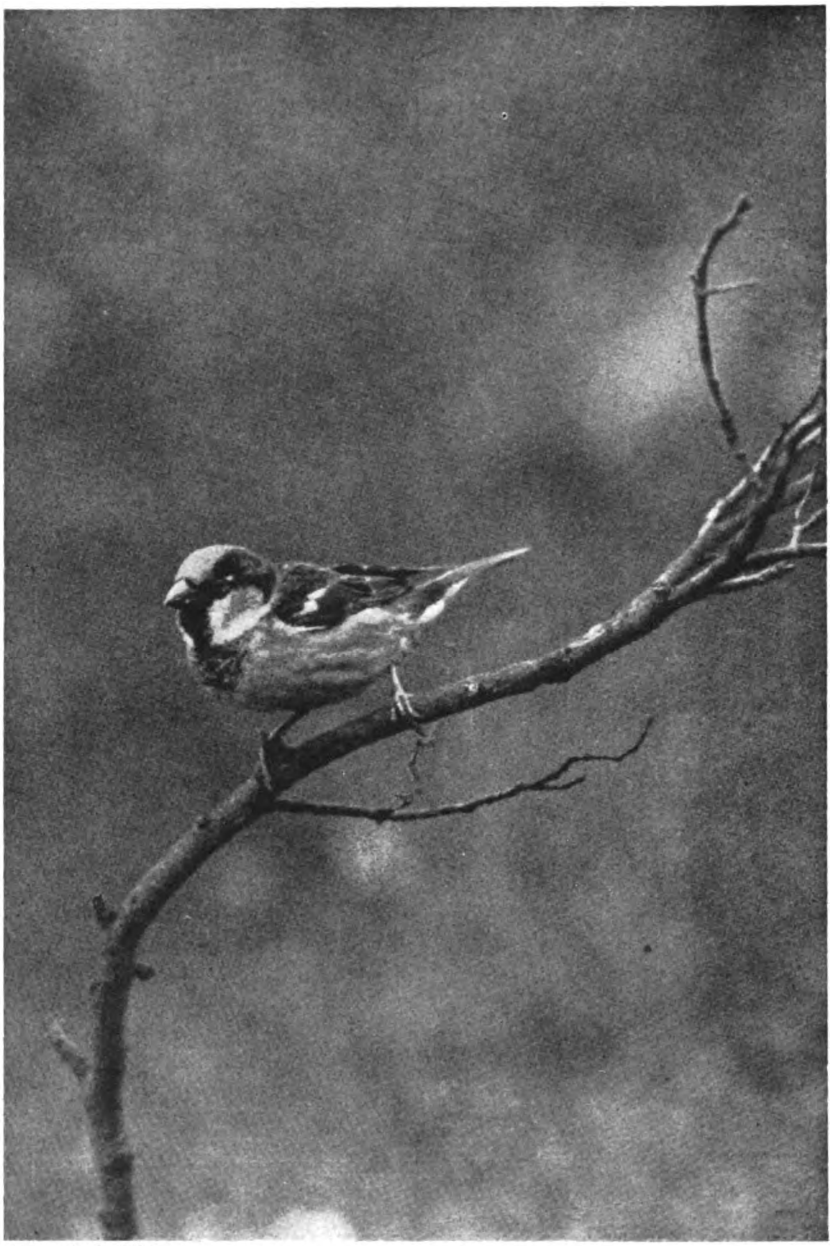


Photo: O. G. Pike.

HOUSE-SPARROW (*Passer domesticus*).

Most familiar of birds, associating itself closely with man, yet always remaining suspicious. Gregarious, prolific, combative, high-spirited, doing considerable harm, but feeding its young with insect larvæ which are in many cases those of injurious species.

the robin. In lonely places it is rare, but wherever a hamlet grows the sparrows make their appearance. And they have contrived to follow man from Europe to distant colonies. The case of the European sparrow in the United States is familiar, but we are slow to learn the lesson of the story. About a dozen times from 1850 onwards the sparrow was deliberately introduced into the United States; about 1,500 were imported in twenty years. The hope was that they would check the ravages of the destructive elm-tree caterpillar, and they did some good in that way. But they found themselves in conditions of material well-being and multiplied exceedingly. They found abundant food, convenient nesting-places, unlimited room, and no enemies. In a few years they inundated the continent and they remain a curse. They destroy crops, they drive away more useful birds, and they are blamed for spreading at least one disease amongst

parents share in feeding the young ones, and as there may be five in the nest this is no light labour of love.

Everyone recognises that the House-Sparrow has attached itself to man in a unique way—which approaches the parasitic. It is not for nothing that it is called *Passer domesticus* but we do not know of any instance of friendliness on the bird's part. It is very different from

poultry. The sparrow is the costliest alien that North America ever admitted.

In recalling this well-known instance of the penalty man has had to pay for interfering unreflectingly with the Balance of Nature, we are not suggesting that the sparrow is altogether against man. It must be kept in mind that the young sparrows are fed on the larvæ of insects, many of which are injurious; and that the

adults never refuse an insect if they get a convenient opportunity. They have been known to destroy green-flies, caterpillars, sawfly larvæ, and other injurious insects; and perhaps they would devour more if man were less careless with his " crumbs." Predominantly, however, house-sparrows feed on grain, seeds, fruits, and buds; and it is pitiful to see the havoc they make of the crofter's exiguous harvest. To be quite fair, one must remember again that some of the seeds they devour and digest are seeds of weeds; but against this has to be put the damage they do in uprooting the sprouting seeds of such crops as peas. There seems to be something like mischievousness in the way they tear up certain flowers, such as crocuses and primroses, but it is possible that they are attracted by the presence of some minute insect.

We cannot leave the sparrow without recalling the interesting observations of Professor Bumpus which ought to be repeated. One winter day in the States, after an uncommonly severe storm a great many sparrows were found benumbed, and 136 of them were brought into the laboratory. The result was that 72 revived and 64 died. Professor Bumpus then made a very elaborate comparison between those that survived and the others. This led to the interesting conclusion that the birds which survived had certain structural characters which those that perished did not possess. In other words there was evidence of discriminate elimination. Those that did not revive were eliminated not fortuitously but because they were unfit. If the weather had suddenly improved there would probably have been a natural selection of the

Photo: M. H. Crawford.

HOUSE-SPARROW'S NEST AND EGGS, WITH ONE NEWLY HATCHED FLEDGLING.

When the nest is built in a hole it is little more than a heap of straws and fibres, cushioned inside with feathers; but large, regularly built, domed nests are often constructed among ivy or on trees, and even in hedgerows. The last year's nest of a House-martin is often utilised, and evictions are known to occur. There are five or six eggs, very variable in colouring. It is believed that the hen does all the brooding. There may be three broods or more in a year.

relatively fitter sparrows. But the elaborate comparison also showed that the process of selective elimination actually observed was most severe with extremely variable individuals, no matter in what direction the variations had occurred. Except in one measured character, the range of variation was greater in those that perished. Nature is against extremists: *Ne nimium* is one of her mottoes. General stability of structure was the essential characteristic of the surviving sparrows.

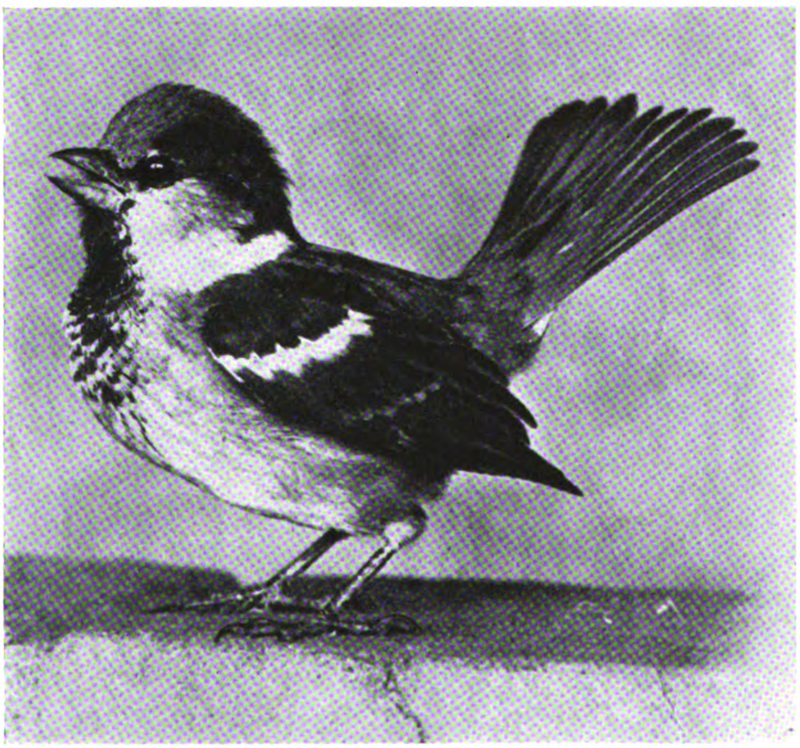


Photo: M. H. Crawford.

YOUNG HOUSE-SPARROW.

The female sparrow has none of the black on the head and throat that marks the handsome male. The photograph shows a young cock-sparrow, just able to fly. It has already assumed most of the characteristic male plumage.

We knew we should find a moral to adorn our tale!

Sparrows in City Streets.

Sparrows are general favourites in large cities, nowhere more markedly than in London. In spite of their ravages among the crocuses in the parks, in spite of their untidy nests, and in spite of their expulsion of finer birds, most people like them not a little. What is at the back of this liking? It is not merely due to the fact that for miles of streets the sparrow may be the only sign of Wild Nature—above the level of insects. It cannot be that there is a wide recognition of the useful part that sparrows play in destroying a great variety of "crumbs," which might attract much less desirable creatures. Few people think in this way.

We wish we could believe that the popular appreciation of the sparrow has an æsthetic basis, but we cannot. No doubt there is a general admiration of the neatly built body and the beautiful movements of flight, but to most people even the cock-sparrow remains "a little brown bird." How few can shut their eyes and see him—see him in his summer dress, a really handsome fellow.

No doubt we admire the sparrow's alertness in rising at the last moment from under the horse's feet or from under the front of the car; no doubt we have sympathy with its plasticity in adapting itself to the difficult conditions of city life; perhaps we commend the bird's virtues as mate and as parent, for sparrows are monogamous, and both cock and hen work hard in feeding four or five nestlings, three or even four times a year. All this is true, but we are inclined to think that our liking for sparrows is largely sentimental. We read the man into the beast, and make a homunculus, i.e., a little man of the bird.

We make it a sort of emblem of cheerful pluck. Not intellectually, but emotionally and in part subconsciously, we say: "Are sparrows downhearted?" Their chirping and twittering on depressing days pleases our fancy. So does their "chapel service" in a park or garden about the time of sunset. We know that they have a hard time, and this enhances our appreciation of their buoyancy. There cannot be many people who know an individual sparrow; we think of them in the mass as a cheerful crew.

Photo: Sport and General.

SPARROWS IN A LONDON PARK.

The so-called House Sparrow, *Passer domesticus*, is widely distributed in Europe and Asia, and has been introduced elsewhere. It remains of course a wild bird, whereas the pigeons seen in London squares are domesticated descendants of the wild Rock Dove, *Columba livia*, still to be found on some of the sea-cliffs in Britain and elsewhere. The large Ring-dove or Wood Pigeon, *Columba palumbus*, with white on neck and wing, is common in London parks. The Stock-dove, *Columba œnas*, is another wild species, not uncommon in Britain; and the Turtle-dove (*Streptopelia turtur*) is a British bird of passage.

And it is in virtue of their gregariousness that they can indulge in their natural aggressiveness.

Mr. Hudson wrote in his inimitable way of the pugnacity of the sparrows at the Tower of London, and their teasing warfare against even pigeons and starlings who have been their neighbours for ages. When a stranger bird appears they hunt him in a pack from place to place " until they have driven him, weak with fatigue and terror, into a corner where they can finish him with their bludgeon beaks." Mr. Hudson quoted that interesting verse from the prophet Jeremiah, suggesting the rough reception birds give to strangers with conspicuous plumage : " Mine heritage is unto me as a speckled bird, the birds round about are against her." Every bird is a " speckled bird " to the pertinacious sparrow.

Mr. Hudson thought that there must be a permanent population of far over a million sparrows in London and a mortality of perhaps five millions every year. Their success depends, in the first place, on their varied bill of fare—all sorts and sizes of " crumbs." The supply has been greatly reduced in recent years with the diminution of horse traffic, the increase of motors, and the use of tarry material on the streets. Sparrows survive, in the second place, because they are many. There are often three broods in a season and there may be five nestlings at a time. There is great plasticity in utilising nesting sites, such as holes in walls, shelters under eaves, the recesses of ivy, and the tangle of bushes in the garden of a square. But besides the long bill-of-fare and the prolific multiplication, there is survival-value in the qualities of alertness, buoyancy, and plasticity, and it is no small thing that the average man has a soft heart to the sparrow!

Mother-of-Pearl.

Among the bivalves whose life-circle is cut by man's, we give a prominent place to the mother-of-pearl oyster, which is the source of much beauty. Even the name is fine! How much greater would be the attractiveness of a book on zoology if all its technical terms were like " mother-of-pearl." Even in German there is pleasantness in " Perlmutter "—a pretty name for a pretty thing. The polished shell of the pearl-oyster makes a plate on which one might hand fruit to a queen, and many beautiful things, such as fans, boxes and brooches can be cut out of it that would " adorn the parlours of heaven." They often seem like crystallised pieces of rainbow, so brilliant is their iridescence.

The shell of a mollusc is a non-living product of a part of the skin that is called the mantle. This forms in bivalves a flap on each side of the body, comparable to the lateral halves of our own jacket. The mantle lines the shell and makes the shell, and it is remarkable in the looseness of its connection with what it makes—very much looser than that between the skin and the shell in a crustacean, such as a crab or a lobster. The mantle of a bivalve, like a clam, is bound to the shell at the attachments of the two shell-closing muscles, and also along a line near the free margin ; but otherwise the shell is strikingly free from the skin. None the less is it true that this skin or mantle is continually making fresh contributions to the shell. These contributions increase the size of the shell along the free margin, and increase its thickness over the whole internal surface. A shell never grows in the strict sense, for there is no life in it ; yet it is continually being added to. In other words, the mollusc's shell is a *cuticle*, which may be defined as an external supporting and protecting covering, not in itself living or cellular, but made (and sometimes re-made) by the underlying living skin.

In many bivalves, such as freshwater mussels, marine mussels, and pearl-oysters, the shell is clearly divisible into three main layers. On the outside, and apt to get worn, is a non-calcareous layer, the periostracum, made of an organic substance called conchin. In a common shallow-water marine bivalve, the clam Lutraria, shreds of this greyish-yellow pellicle can be easily torn off the outside of the shell, and it is interesting to notice that it is continued into a transparent jelly-like sheath over the long breathing-tubes of this sand-burrowing species. When we pull off a piece of the pellicle or of the gelatinous sheath, and hold it against the light, we are looking at pure conchin, which may be called the most characteristic chemical product of molluscs. It should be contrasted with the chitin of crustaceans, insects, and spiders, and with the horn or keratin of the reptile's scale, the bird's feather, and the mammal's hair. A mollusc is known by its conchin.

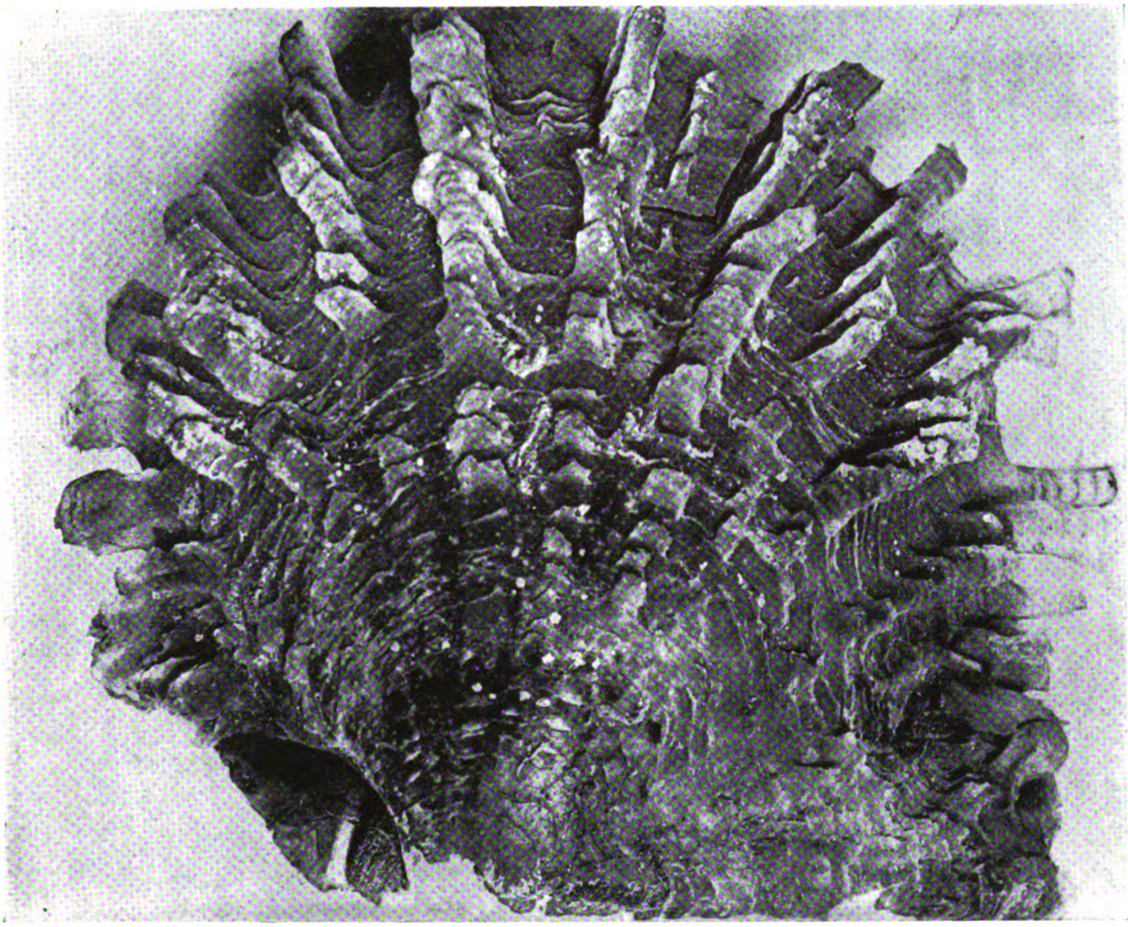


Photo: Exclusive News Agency.

THE OUTSIDE OF A MOTHER-OF-PEARL SHELL (*Avicula margaritifera*).

The source of Mother-of-Pearl is a bivalve related to the true oyster. It is widely distributed in the Indian Ocean, and in waters off Queensland, Lower California, Panama and elsewhere. The internal nacreous layer is cut into knife-handles, buttons, studs, and the like. The rough outside shows lines of growth and rough prominences which may prevent shell-boring snails from getting a grip.

Beneath the organic outer pellicle comes the prismatic layer, often the thickest part of the shell, where the carbonate of lime is laid down in prisms of calcite (as in pearl-oysters and marine mussels), or in prisms of aragonite (as in freshwater mussels). Calcite and aragonite are both carbonate of lime, but differ in hardness, specific gravity, and mode of crystallisation. Each calcite prism corresponds to a crystal-unit of calcspar; the aragonite prism is built up of "sphero-crystals." Internal to the prismatic layer is the mother-of-pearl, consisting of platelet crystals of aragonite and typically, though not necessarily, showing a beautiful, iridescent lustre. Thus for shells like those of the pearl-oysters or of the freshwater mussels, we may use an alliterative mnemonic. The three layers are periostracum, prismatic, and pearly.

But whenever we probe into these matters a little we find diversity and complexity. Thus many shells, as of scallops and edible oysters, have the innermost layer made of calcite, often in the form of very narrow platelets; and in the majority of marine bivalves and gastropods the inner lining of the shell is like porcelain, consisting of needle-like or fibre-like crystals of aragonite, often united into platelets. To find the three-layered shell-structure we should look in the first instance for members of the families already mentioned—pearl-oysters, marine mussels, and freshwater mussels. The mother-of-pearl layer is well seen in the Pearly Nautilus, the only living cuttlefish or Cephalopod mollusc that is ensconced inside a shell. Or, again, in the polished top-shells (Turbo and Trochus) so often and deservedly used for ornaments, the

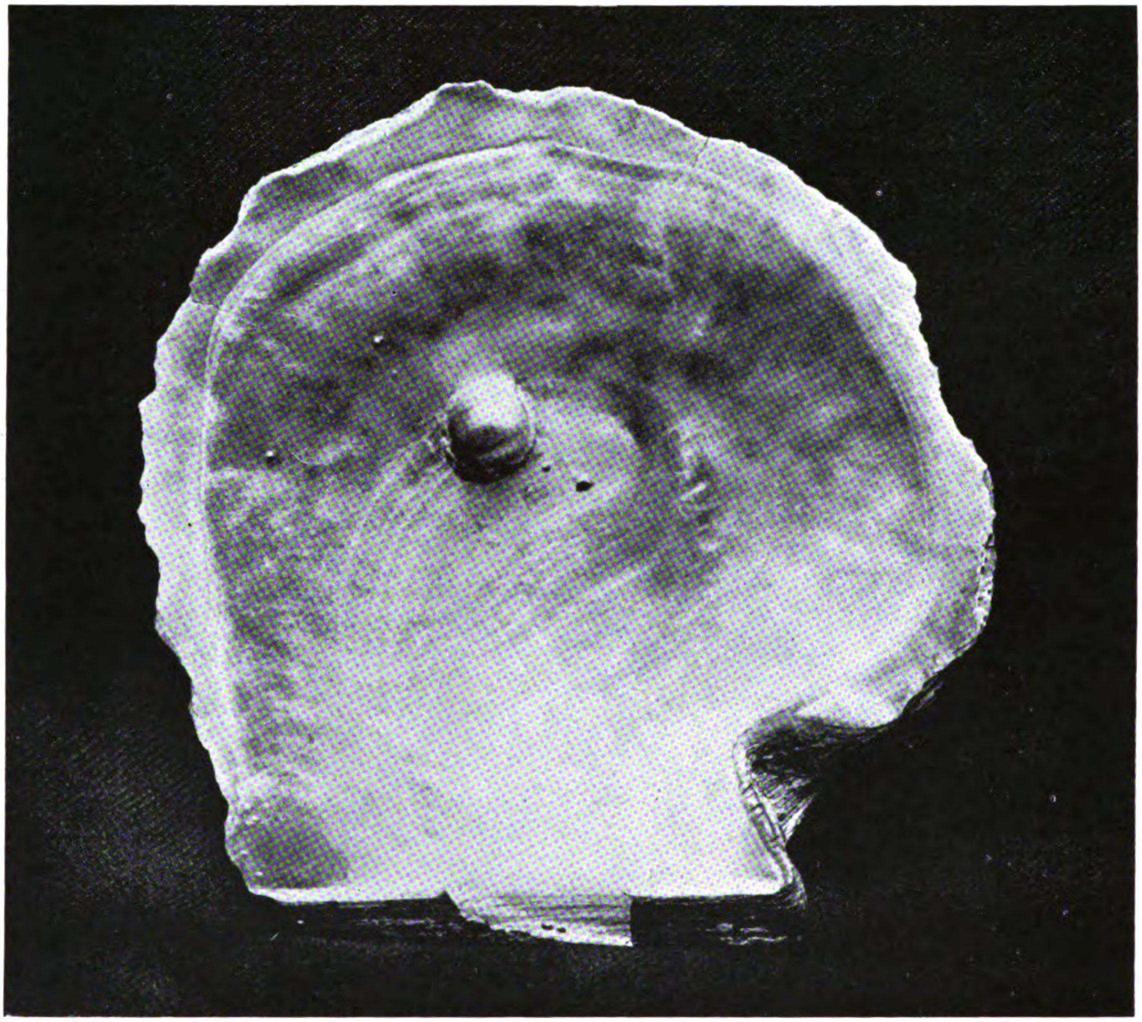


Photo: Underwood Press Service.

INSIDE OF MOTHER-OF-PEARL "OYSTER," SHOWING A LARGE PEARL EMBEDDED IN SHELL.

The shell of any typical bivalve mollusc, such as cockle or mussel, oyster or clam, shows: (1) an outside purely organic layer (of conchiolin), (2) then a substantial layer of lime (often laid down in prisms), and (3) innermost a nacreous or mother-of-pearl layer, which may be thick or thin, yet always shows fine platelets or lamellæ that are formed in regular and harmonious succession as growth continues. The finest pearls are not fixed to the shell, but are free in pockets of the mantle that lines and makes the shell.

unmistakable mother-of-pearl has been brought to the surface by scouring off the other two layers. The question that especially concerns us at present is as to the nature and origin of the mother-of-pearl layer, and we are relying mainly on recent researches by Professor W. J. Schmidt, of Bonn.

It has been known for a long time that mother-of-pearl consists of very thin plates or lamellæ, partly organic and partly calcareous, laid down parallel to the surface of the shell. Over the surface next the mantle one plate is deposited after another, and the shell increases in thickness. At the free margin, as long as the mantle grows, there are fresh contributions laid down which make the shell larger.

The whole internal surface of the mother-of-pearl, except where the muscles are inserted, shows under slight magnification a multitude of close-set curved lines, such as one sees in the graining of wood or on an engraving. There is an alternation of brighter spots or lines, where the surface is smooth and continuous, and duller spots where the surface is broken into multitudinous particles more or less separated by gaps. As these gaplets become filled in, the duller spots become brighter and the inner surface of the shell becomes continuous. Instead of the mother-of-pearl surface being, to begin

with, a continuous smooth layer, it shows in the growing zones a fine relief, a graining, a multitude of minute terraces at different levels. The fact is that the mother-of-pearl is built up of minute isolated contributions, which eventually grow together and coalesce to form plates of nacre. But the whole internal surface of the shell is often far from being at the same level; there is, as we have said, a system of terraces. The individual items that make up a minute plate of nacre are rhombic crystals of aragonite, varying in their details of form, and they take shape and arrangement outside the living skin altogether.

At the margin of the shell, on a foundation furnished by the edge of the prismatic layer, the mother-of-pearl extends not its thickness, but its area. The mantle secretes the organic substance called conchin, with gas-containing bubbles, and amidst these there appear isolated disc-like platelets or crystals of aragonite. These platelets coalesce into a primary plate or lamella, and it must also be borne in mind that they are, as it were, cemented together by an inconceivably thin mortar of conchin.

The big fact is that the mother-of-pearl is the outcome of a process of crystallisation. It is built up of successive layers; these are built up of primary plates; these again are due to a coalescence of numerous platelets which are crystals of aragonite. The living mantle supplies the raw materials and determines the limits and rates of growth, but the form of the building stones (rhombic crystals) and the manner in which they are fitted into one another must be put to the credit not of life but of lime! Yet the marvel to us is that "life," working through the rhythmic growth and activity of the mollusc's skin, has, after all, the last word in determining the particular architecture of the shell in all its rich variety. What comes from the mantle is a "colloid" secretion of conchin with carbonate of lime in solution. This is formed by a surface and by an edge of skin, which varies in detail from type to type; and we are inclined to differ from Professor Schmidt in attaching more importance than he will allow to the fluctuations in the growth and life (metabolism) of the mantle.

We have not alluded to the connection between the structure of the mother-of-pearl and the optical properties which give it so much charm. That is a quite separate problem, really outside biology, and for the most part solved. We have also skipped another question, which

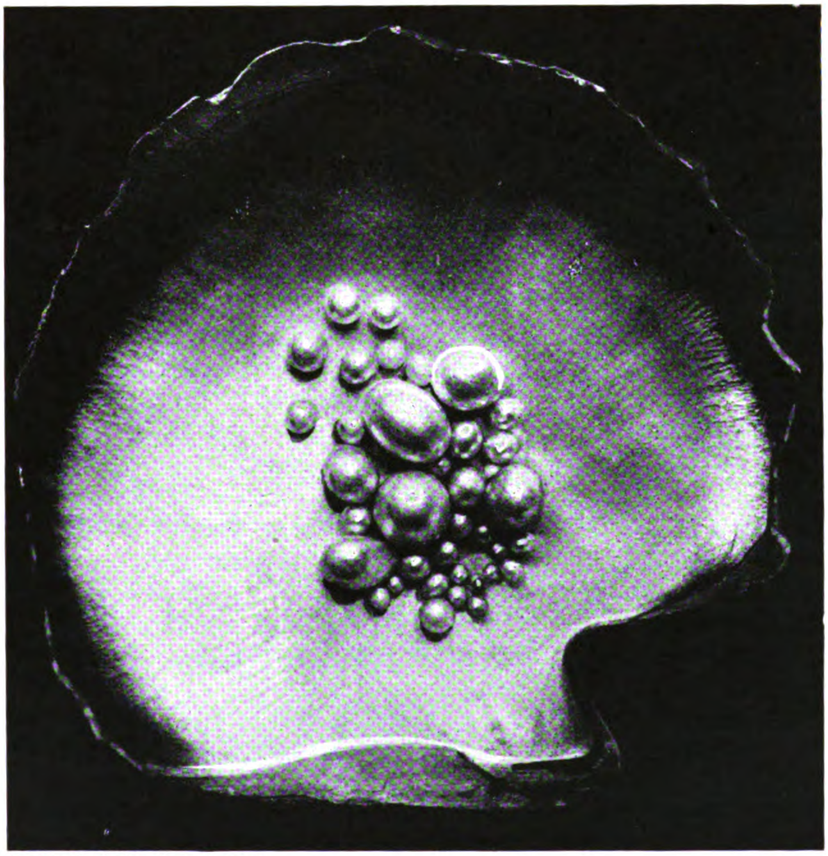


Photo: Exclusive News Agency.

A WEALTH OF PEARLS.

This beautiful picture shows six "fine" pearls from the Queensland pearl-oyster and numerous small ones besides. The opalescence of a "fine" pearl is a physical effect due to the numerous concentric layers of lime and conchin in the structure of the pearl—the making of which is an abnormal side-track in vital processes, but nevertheless extraordinarily beautiful.

is not easily answered: *How does the prismatic layer grow in thickness?* But we have perhaps said enough to show how the chemist joins hands with the naturalist; and though the subject is difficult, everyone should be able to answer in a general way the question: *How does a mollusc make its shell?*

Man's Natural Enemies.

It is very important to think of man's multitudinous enemies among animals and among plants too. For this was the earliest phase of man's struggle for existence—a struggle that helped to make him what he is. He had to hold his own against beasts of prey stronger than himself and against venomous snakes. He had to learn to distinguish between poisonous plants and those that were useful or indifferent.

This primitive struggle doubtless meant much for man, and for many ages it must have continued on rough-and-ready lines before the results of experience began to be gathered and registered as *lore*. Very gradually, for the most part in recent years, man began to use science to help him to master or to circumvent his natural enemies. Thus an anti-toxin treatment has been found effective in baulking the effects of snake-bite. Or hay fever, now shown to be an extreme irritation which some susceptible persons experience when they sniff up the pollen of grasses and some other plants, may be counteracted by injection-treatment, which is the outcome of exceedingly difficult and intricate biological research. Perhaps a better instance might be found in the modern differential treatment of weeds, which are more hostile to man than the directly injurious "poison-ivy" and the like. Thus the yellow charlock, one of the worst of weeds, may be treated with a spray of copper sulphate, which runs off the smooth and erect leaves of the cereals, but gathers on the rough, more or less horizontal, leaves of the weed. Or the field may be dusted with finely powdered kainit—a potash manure containing a considerable proportion of common salt. This is most profitably applied when the weed is young, when its leaves are wet with dew, and when a sunny day follows. The kainit kills the charlock and it also helps to manure the soil. This instance of man's increasing control is of considerable interest in itself, and we have given it because it is typical of many. It illustrates the use of a particular method—*discriminate elimination*—which Darwin recognised as characteristic of the whole process of Organic Evolution. One may say that the modern weed-eliminating farmer is "following nature": from another point of view he is applying a very theoretical conclusion to an urgent practical problem.

The Serpent.

From the dawn of history the serpent has been classed as the traditional foe of man, and for that reason it may not be out of place to speak of these reptiles in the present part. The widespread belief in the wisdom of the serpent does not seem to have much zoological justification. Efficiency in movement, in food-capture, in attack and in disappearance—all that they show at a high level, but wisdom is far to seek. As we have seen in an earlier chapter, what the snake does is in virtue of engrained hereditary capacities which work well, but there is not much evidence of plastic intelligence or judgment. When an animal's inborn equipment is sufficient to enable it to cope with nine out of ten difficulties in everyday life, it is not likely to show much understanding. It is rare for an animal to show more intelligence than it needs. Even when the mind of the snake finds expression, it is not what could be called brilliant.

Snakes have a restless tongue, which is whipped out and in as a touch-organ, and seems to be very sensitive. The eyes are well developed, though lacking one of the usual muscles—the retractor. The risk of injury when the animal is creeping among obstacles is lessened by the fusion of the lower eyelid to the upper. The result is a complete transparent blind over the front of the eye. The immobility of the lids gives the snake its unlimited capacity for staring. The Scriptures speak of the deaf adder that stoppeth her ear, and although they have no ear-hole that they could stop, the description conveys a good idea of their listlessness to most sounds. They have no drum to the ear, and it is safe to say that hearing does not count for much in their life.

In the mysterious movements of serpents, their elusive ways, and their frequent deadliness, we must find the basis for a wholesome respect which has credited them with a wisdom greater than they possess. From very early days serpents have been symbols of the dæmonic powers

of the earth, and it is one of primitive man's ways to transfer to a symbolic animal the virtues or abilities of the Power which it symbolises. Thus, the serpent has greater subtlety than any other beast of the field, and a somewhat commonplace mentality has been invested with extraordinary wisdom.

Snakes have been given credit for doing many things that are impossible or vastly improbable. Eye-witnesses notwithstanding, it is impossible that a snake should put its tail into its mouth and make a hoop or wheel of its body. Even if it knew it would become a symbol of eternity if it succeeded, it could not do it. It is said that one snake may begin to swallow another which is at the same time engaged in swallowing it; and this has been used by profane persons as a symbol of logic. It is vastly improbable that any mother snake ever temporarily swallows her young ones, even to save them from great danger. The description of the thrilling scene has been given by people who got it at first hand from a friend, whose nephew dissected a snake in Australia and found young ones inside. Viviparous snakes are well known, but the oviduct is different from the food-canal. One must remember, however, that among fishes and frogs there are cases known where the male parent at the breeding season always shelters the eggs and the young ones inside his mouth. So we have not said that it is impossible for the mother snake to save its young ones by swallowing them for the time being, we have only said that it is vastly improbable. We have heard several accounts, but none that we could swallow.

We are sceptical, likewise, in regard to the snake's susceptibility to the soothing influence of music, said to be illustrated when the wily Hindu pipes to the "charmed" cobra. The poor cobra has had its poison-fangs wrenched out, and often at least its behaviour is under coercion. It was a better trick that the Egyptian magicians played before Pharaoh, turning snakes into sticks and back again. For that is the well

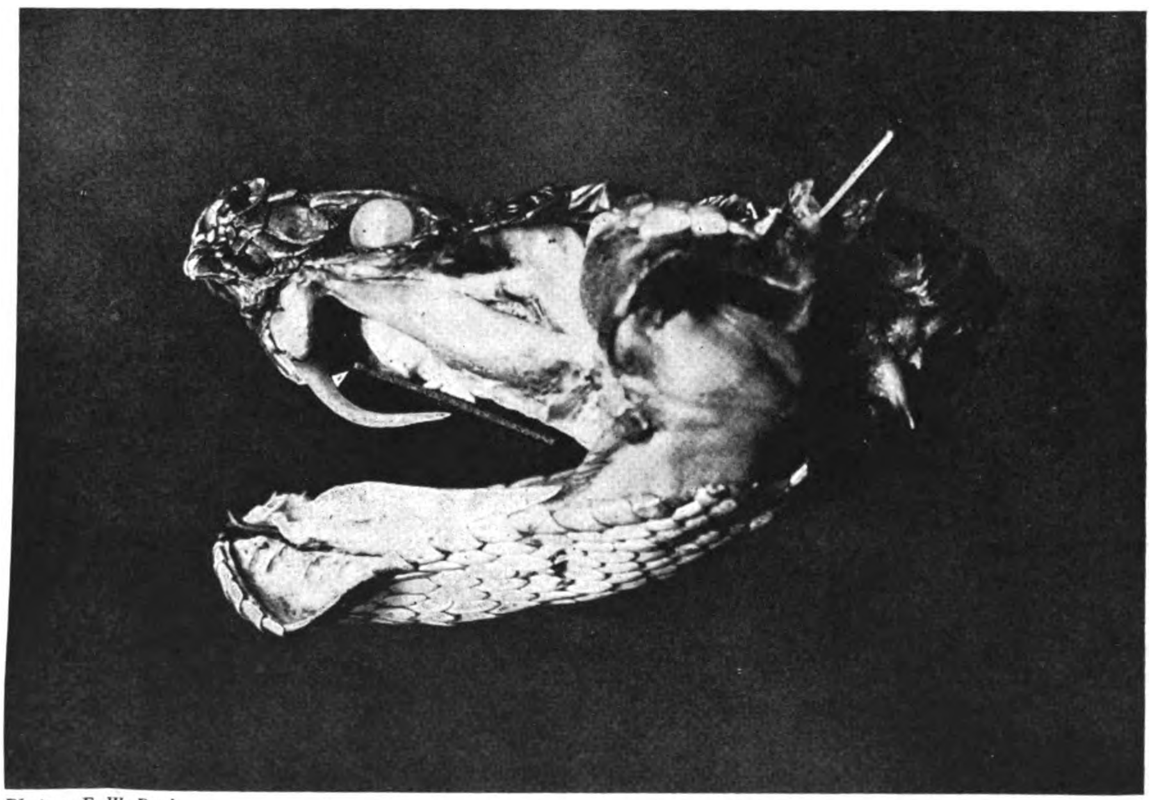


Photo: F. W. Bond.

HEAD OF RATTLESNAKE (CROTALUS), DISSECTED TO SHOW THE POISON-GLAND.

Behind the upper jaw lies the poison-gland, a transformation of the parotid salivary gland. A duct passes forward along the side of the upper jaw to the specialised tooth that forms the fang. It opens in the sheath at the base, and the poison passes up a canal inside the fang, with an opening near the tip. The opening of the lower jaw automatically squeezes the venom out of the gland. Between nostril and eye there is a sensory pit.

known phenomenon of animal hypnosis—a peculiar fatigue-state of the nervous and muscular systems. The snake is held firmly by the tail and just behind the head. Orders pass out from the central nervous system commanding the muscles to contract. But no proper contraction is allowed, and the result of this contradiction in terms is that the animal soon becomes stiff and motionless: it lies inert without being held. The snake becomes a stick. By and by, the blood begins to circulate freely, the fatigue effects pass off, the wheels begin to go round again, and the stick becomes a snake. But there is no wisdom here.

We are inclined to say the same in regard to those snakes which "feign death" when they are suddenly and hopelessly cornered. Perhaps we are wrong—the subject requires further investigation—but it is probable that the "lying low" is closely akin to animal hypnosis. It is a state into which the animal passes, reflexly, not reflectively, when it gets a sudden shock or is quite baffled. In all likelihood it is at a much lower level than the "playing 'possum" exhibited by a genuinely clever animal like a fox. But there are experienced naturalists who would be more generous to the snake than we see our way to be.

Dr. Hornaday is director of the New York Zoological Park, and has a large experience of snakes and many other animals. It is fair therefore to notice that he would not agree at all with the tone of our remarks. In his "Minds and Manners of Wild Animals" (1922), he speaks of "the keen intelligence and ratiocination" of snakes, basing his belief on "the success of all species in meeting new conditions and maintaining their existence in face of enormous difficulties." But efficiency is not the same as intelligence, and alertness is not ratiocination. Dr. Hornaday says again, "I have emerged with a fixed belief that, of all vertebrate creatures, snakes are the least understood, and also the most thoroughly misunderstood. The world at large debits serpents with being far more quarrelsome and aggressive than they really are, and it credits them with knowing far less than they do know." This authority attaches great importance to the case of a Reticulated Python, twenty-two feet long, which had been on its long journey from Singapore, "unable to shed its old skin on schedule time," and had to be peeled to save its life. At first it writhed and resisted, but the five keepers "worked quietly and spoke soothingly," and all went well. "For a long hour or more, and even when the men pulled the dead scales from the eyes and lips the creature made no resistance or protest. I have seen many people fight their doctors for less. That wild, newly caught jungle snake quickly had recognised the situation, and acted its part with a degree of sense and appreciation that was astounding. I do not know of any adult wild mammal that would have shown that kind and degree of wisdom under similar circumstances." We have great respect for the experience behind Dr. Hornaday's conclusions, but they seem to us over-generous. Perhaps it depends on what is meant by "wisdom." Our main point is that snakes have engrained or inborn reaction-capacities which are sufficient for the ordinary problems of life, and that when something unexpected happens they manage to wriggle out of it with credit. If they were less efficient they might perhaps be more intelligent.

We almost forgot to say that we do not believe in snakes "fascinating" birds. We have watched what happens—a sight tolerable only in the interests of bio-psychology—and it seemed to be a clear case of fear-paralysis. The birds were dazed with fear; they moved stiffly twice or thrice, and then stood rigid. We have seen a a pony so "fascinated" by a motor car that we had to share in lifting it, like a frozen animal, off the road. So even in regard to the so-called "bird-charming," what impressed us was the efficiency of the snake, not its wisdom.

The Fly on the Wheel.

How true it is that the little things of this world are often able to confound the strong. Size does not count for much. The giant falls before a microbe and the germs of some diseases are so small that they have never been seen at all—even with the ultra-microscope. Darwin was one of the first to be vividly impressed with the summed-up importance of little things in the world of life; for did he not prove that earthworms have made most of the fertile soil on which everything else depends? Pasteur was even more convincing with his demonstration that many diseases are due to almost inconceivably minute microbes. But neither of them had any idea of the importance of insects in the

spread of human diseases. In fact that must be called a modern discovery, and it may be of interest to set in order some of the steps which have led to our knowledge of the part played by the fly on the wheel of the chariot of civilisation.

Long before Darwin, it had been recognised by the Berlin botanist, Sprengel, that insects often carry the fertilising pollen from flower to flower, which is one of the most important linkages in the world. The semi-domestication of hive-bees and silk-moths is a very old story, and in many other ways the occasional utility of insects had been recognised. Men often made meals of locusts, palliated with wild honey, and various insects figure in the list of old-fashioned "animal simples" — the supposed cures for many diseases.

On the other hand, it did not need zoology to acquaint man with the ravages of locusts and other obvious plant-destroying insects; with the unpleasantness of hornets, mosquitoes and lice; or with the contamination of flesh-food by flies. But apart from popular suspicions and a few pioneer guesses at truth, the idea of insects as carriers of disease is only about half a century old.

In warm countries the blood of man sometimes contains multitudes of microscopic thread-worms or *filarias* which may bring on a horrible thickening of the arms and legs called *elephantiasis*, because suggestive of an elephant's hide. The carrier of this very minute worm is a mosquito, as was proved by Dr. Patrick Manson. This, we believe, was the first case in which a disease was conclusively shown to be insect-borne. The discovery was very important in itself, but not less so in its introduction of a new and revolutionary idea. It should be recalled that Manson reached his conclusion by patient work under difficult conditions and in the face of an indifference which was much more discouraging than incredulity.

The microscopic animal (Plasmodium) that causes malaria was discovered in 1880 by Dr. Laveran, a French Army surgeon, working in Algeria; but the definite proof of the mosquito's rôle as the intermediate host between man and man was given by Sir Ronald Ross in 1897. After years of toil and trouble he found the malaria organism in the cells of the stomach of the "dapple-winged mosquito," and this discovery must rank as one of the most important that man has ever made. The "dapple-winged mosquito" may be captured in many parts of Great Britain to-day, but

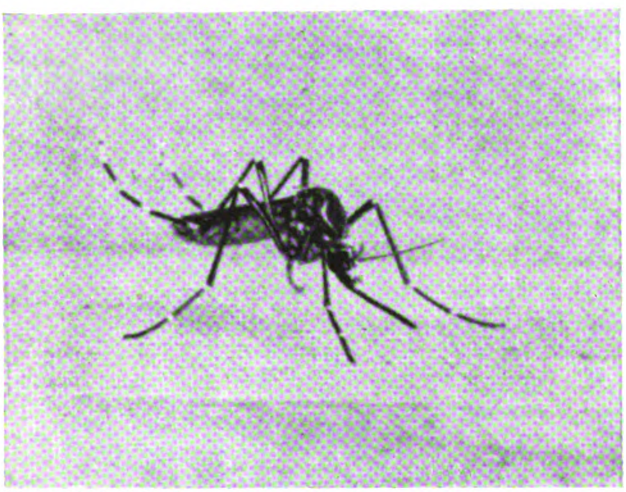


Photo: Hugh Main.

MALE YELLOW FEVER MOSQUITO (*Stegomyia fasciata*).
Mosquitoes are gnats in the family Culicidæ, and there are ten or a dozen different kinds in Britain, including the Dapple-wing (*Anopheles maculipennis*) which carries the germ of malaria in countries like Italy, and used to do so in Britain as well. In most cases it is only the adult female that bites, but there seems to be no real need for her taking any food at all. The feeding is done in the aquatic larval stage.

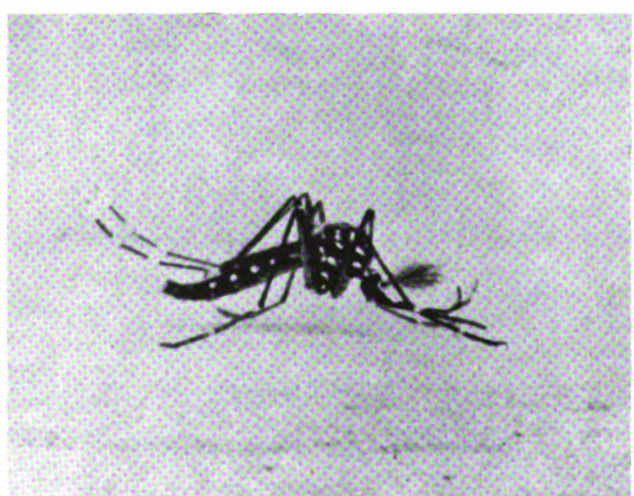


Photo: Hugh Main.

FEMALE YELLOW FEVER MOSQUITO (*Stegomyia fasciata*).
This particular kind of mosquito is the vehicle or disseminator of the microbe (a Spirochæte) which causes yellow fever in warm countries. The eggs do not hatch at a temperature less than 68° Fahrenheit, and below 62° F. the females do not bite. The hairs or setæ on the feelers of the male insect are numerous, but on the female they are scanty. In many places, through a knowledge of the life-history of this mosquito and the habits of the aquatic larvæ, yellow fever has been conquered.

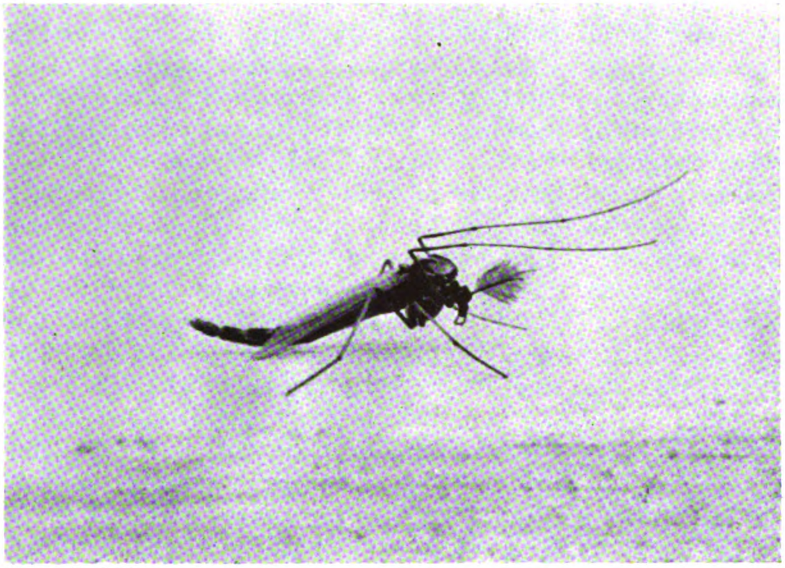


Photo: Hugh Main.

LATERAL VIEW OF MALE HARLEQUIN FLY OR MIDGE (*Chironomus*).

The Harlequin Fly is gnat-like in form, but it is a harmless midge. It has no projecting proboscis and no piercing mouth-parts. In all probability the winged adults do not feed at all. When they are resting, the front legs are raised and held forwards like feelers; gnats usually raise their hind-legs when at rest.

it seems to have ceased to carry the malaria germ. We should remember, however, that it used to do so, for the old and widespread "ague," sometimes so serious that it interfered with farming operations, was the same as malaria. But Sir Ronald Ross has given mankind the knowledge that makes the conquest of malaria relatively easy whenever people have sufficient energy and goodwill.

Influenced by Ross, and worthy of being linked with him, was Walter Reed, who proved in 1900 that the vehicle of the deadly Yellow Fever organism is the common house-mosquito of tropical America. His experiments in Cuba were models of carefulness; and it is very significant that in one year's campaign conducted by the famous General Gorgas, yellow fever was ousted from Havana where it had been a scourge for 150 years. General Gorgas had similar victories elsewhere, notably in the zone of the Panama Canal. He was the organising genius who acted on the scientific conclusions which Reed had established. In all these cases there has to be team-work, and while we have laid emphasis on the work of Reed, we are not forgetting that others had *thought* that Yellow Fever might be carried by a mosquito, and that he had loyal collaborators.

One of these fell a victim to the fever, and another, along with Reed himself, died soon after the discovery, all three having indirectly, if not directly, given up their lives in the Cuban experiments. The probable cause of the disease, according to the investigations (1919) of Dr. Noguchi, is a Spirochæt, a microscopic organism allied to that which causes relapsing fever. Noguchi also prepared a useful counteractive vaccine, but the conquest of Yellow Jack depends on

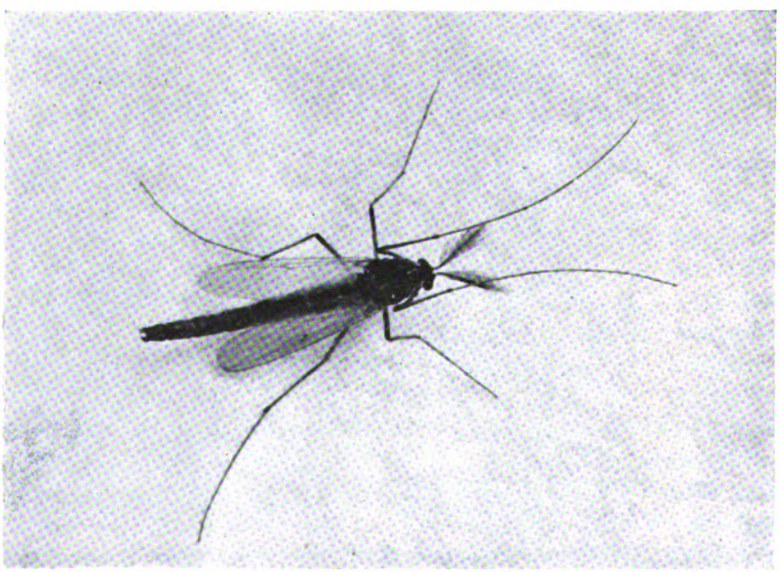


Photo: Hugh Main.

DORSAL VIEW OF MALE HARLEQUIN FLY OR MIDGE (*Chironomus*).

As in true gnats, the male of the Harlequin Fly has beautiful plumose feelers or antennæ, whereas those of the female are narrow and rather inconspicuous. The larvæ are aquatic, and swim rapidly by contorting their bodies like harlequins. They are bright red in colour and are popularly known as "blood worms." They have the same blood-pigment (hæmoglobin) as we have.

Photo: John J. Ward, F.E.S.

EGGS OF BLOWFLY.

The Blowfly or Bluebottle (*Calliphora vomitoria*) lays about two hundred long, narrow, minute eggs on meat, where rapid development takes place.

Photo: John J. Ward, F.E.S.

MAGGOT OF BLOWFLY.

The white legless maggots, known to anglers as "gentles," burrow into the meat and feed voraciously, attaining their full size in four or five days. The narrow end is the head.

Photo: John J. Ward, F.E.S.

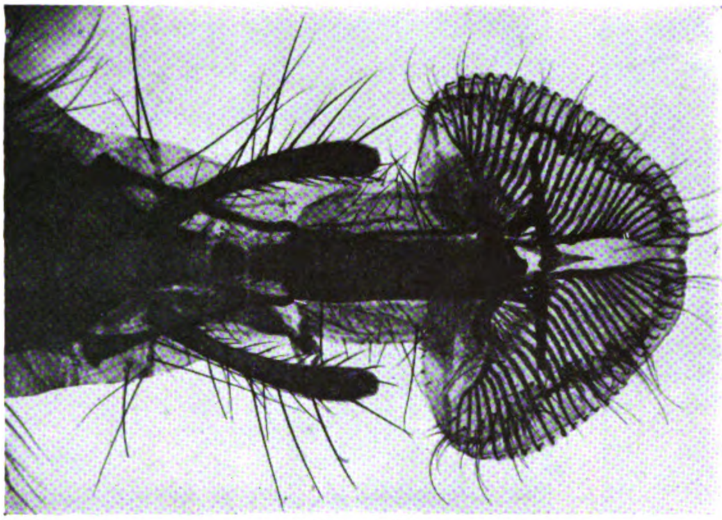
BLOWFLY MAGGOT CHANGING TO PUPA STAGE.

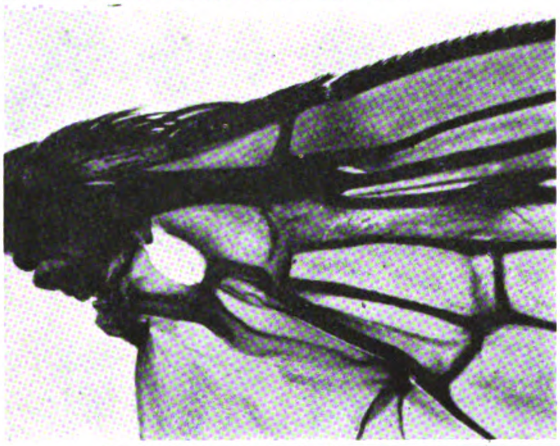
From the meat the full-grown maggot passes into the earth or some sheltered corner, and forms a brown pupa-case. The larval body is dissolved ; a new body is built up

Photo: John J. Ward, F.E.S.

BLOWFLY JUST EMERGED FROM PUPA CASE.

When metamorphosis is accomplished, the insect beats with its head on the wall of the pupa-case and breaks off one end. It emerges, spreads its wings, and flies away.





keeping out the mosquito.

Sleeping Sickness is one of the severest scourges of mankind, not merely because it kills, they say, about 50,000 natives every year in Equatorial Africa, but because of the terrible symptoms — lethargy, emaciation, and mental breakdown. Its specific cause is a Trypanosome, a very active Infusorian, which lives in the blood, the lymphatic glands, and the nervous system of man, and produces a deadly toxin or poison. But while a microscopic Protozoon is the cause, the Tse-tse fly is the carrier, as was proved by Sir David Bruce and others. How the particular kind of Tse-tse fly (*Glossina palpalis*) that bites man becomes itself infected with the Trypanosome is uncertain, but Bruce showed that another Trypanosome, with which another kind of Tse-tse infects horses and cattle, has its home, so to speak, in the blood of antelopes and other "big game." To these, however, it seems to do no harm. The accustomed host of a parasite has often evolved a counteractive or anti-toxin which prevents serious damage. It is transference to an unwonted host that is so deadly.

In Malaria and in Sleeping Sickness the actual cause is a microscopic animal and the carrier an insect. Many other diseases are due not to Protozoa but to Bacteria, which are included among the simplest plants, and here again insects are often the vehicles of dissemination. Thus the plague, the old "Black Death," is due to a Bacillus which is primarily at home in the rat. It is introduced into man by the bite of the rat-flea. Typhoid fever, due to another Bacillus, is also often carried by the house fly which introduces it into man's food.

Photos: John J. Ward, F.E.S.

PARTS OF THE BLOW-FLY.

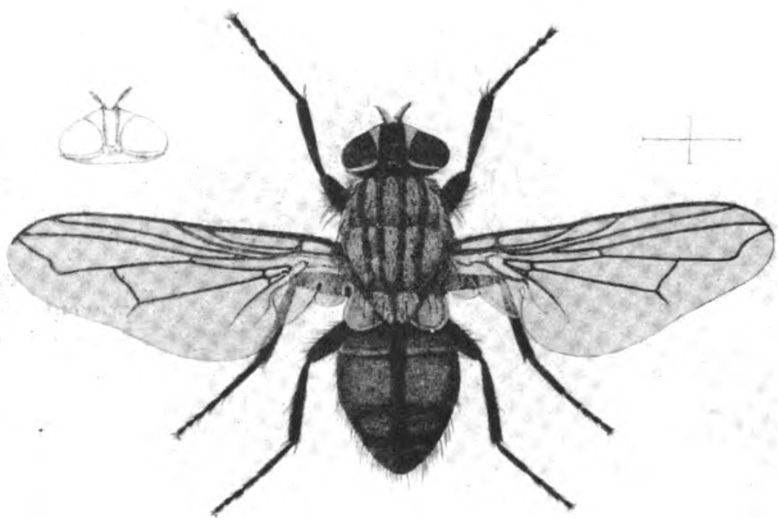
(1) A view of the mouth-parts under the microscope, showing, for instance, a pair of small unjointed palps and the very characteristic suctorial proboscis traversed by many delicate canals. (2) The base of the wing, showing the strengthening "veins" or "nervures." The hind-wings are changed into "poisers." (3) The end of the foot, bearing two claws and two adhesive pads with fine hairs or setæ that secrete a sticky fluid.

Specially drawn for this work by Roland Green, F.Z.S.

COMMON SNAILS (*Helix*).

The two lower figures show the Common Garden Snail, *Helix aspersa*, at rest and in active movement. The colour of the thick shell is yellowish with interrupted spiral dark reddish-brown bands, often five in number. On the longer tentacles or horns there are black eyes, but the animals do not seem to see much. The upper figures show the much larger Roman Snail, *Helix pomatia*, with a shell about $1\frac{3}{4}$ inch across, yellowish, or pinkish-white, in colour. In all these snails there seems to be a sense of smell in the long horns, and perhaps in the shorter ones as well.

These illustrations of the fly on the wheel show the immense importance of the vital linkages which bind living creatures together even when they seem very far apart. They also show how man conquers by understanding, and is persistently removing unnecessary handicaps by a growing control of life. He is continually taking great risks, and it seems sometimes as if he made new enemies as fast as he conquered the old. But it is always progress to get the better of enemies that sift mankind without discrimination, taking the wheat along with the tares.



Reproduced from "The House-Fly," C. Gordon Hewitt, D.Sc., F.R.S.C., by courtesy of the publishers, the Cambridge University Press.

THE FEMALE HOUSE-FLY (*Musca domestica*).

Several species of fly occur in our houses; the true House-fly is mostly greyish, with some yellow posteriorly, with four black streaks running longitudinally along the front of the thorax, and a single streak on the abdomen. The inset shows the head of the male.

There are various insects which are unmentionable in polite society, and the flea is one.

The Nimble Flea.

Or, rather, it is many, for about five hundred different kinds have been described, and forty-six of them are found in Britain. We do not know why there should be such a multitude of different species, except that it means that fleas have discovered a profitable mode of life—an elusive "ecto-parasitism." Few naturalists will agree with us, but we doubt very much if they should be called parasites at all; they are more like beasts of prey whose bites are so microscopic that they do not of themselves amount to much—only "flea-bites." The flea has been called the homœopathist's leech, and one would not call the leech a parasite, would one? But this is perhaps hair-splitting; whatever terms are used, everyone knows,

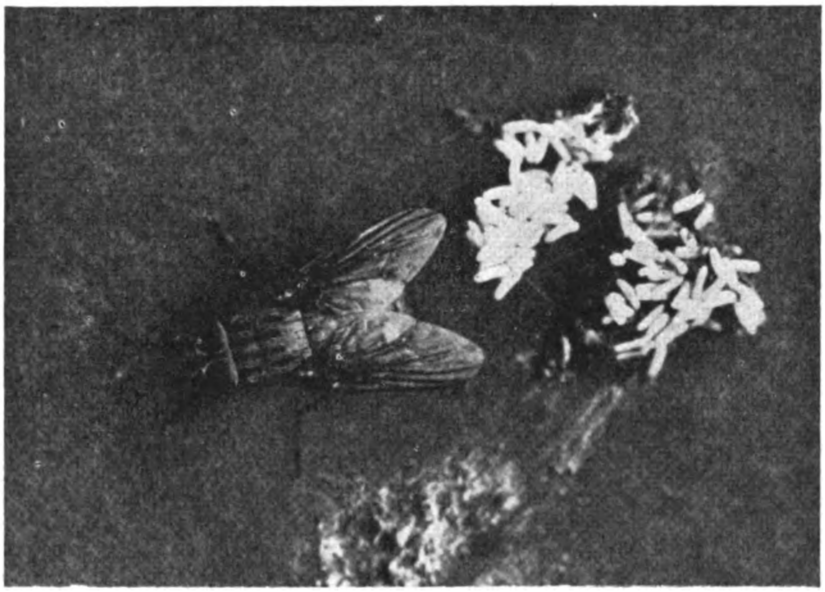


Photo: John. J. Ward, F.E.S.

HOUSE-FLY (*Musca domestica*) WITH ITS BATCH OF EGGS.

Over a hundred minute white eggs are laid by the female on any moist organic rubbish on which the larvæ can feed. After a day or two the white legless maggots are hatched out; in less than a week they become pupæ; in about a fortnight the flies emerge.

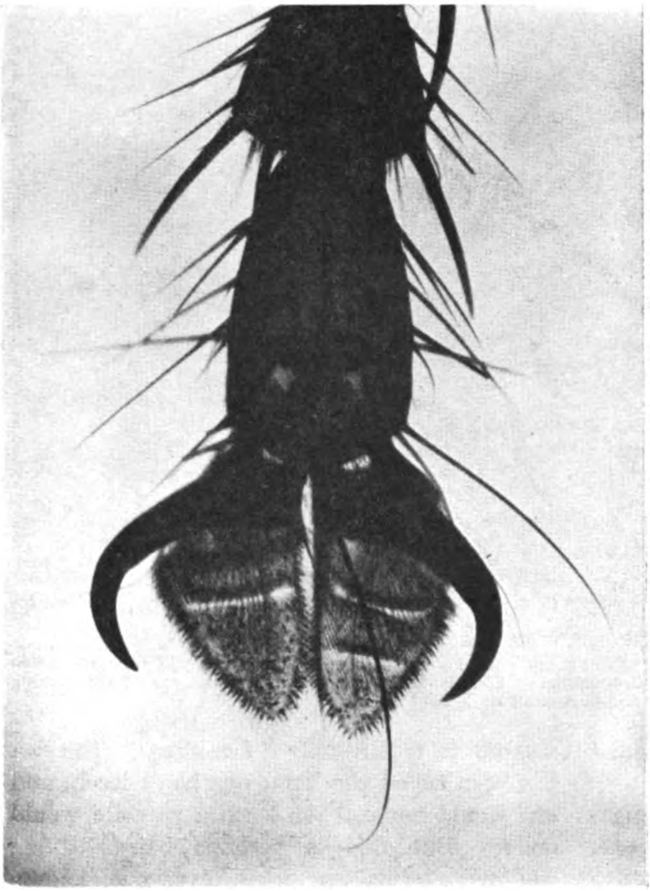


Photo: John. J. Ward, F.E.S.

FOOT OF HOUSE-FLY. (Highly magnified.)

The foot of the House-fly ends in five short joints, called the tarsals, and the last of these bears a pair of claws. Under each claw is a cushion-like pad, which is covered with fine hairs, on which a sticky adhesive fluid exudes.

pumps, one for injecting salivary juice into the victim and another for drawing up the blood and forcing it through a valved gizzard into the stomach, where it is digested. Partner-yeasts live in the salivary glands, and their ferment probably increases the local blood pressure in the so-called "host," and prevents clotting. The irritation of the flea-bite, which seems out of all proportion to the minute and neat wound, is presumably in part due to the introduction of the yeast, and, it may be, other micro-organisms, into the blood of the victim. The effect on different individuals is very diverse, depending on the anti-toxic state of the blood at the time.

Alike in promenading and in jumping, the flea displays great energy, and we are not surprised to find that it has a relatively large heart and a finely developed respiratory system. There is almost no hint of the parasite in its structure except that some kinds of fleas are blind. Socrates once condescended to inquire how far a flea up to a variable point, what fleas are and do.

Some structural features are of interest. The body is compressed from side to side, whereas most parasitic insects are flat from above downwards. There is neither neck nor waist. The body is strongly armoured, and bears numerous backward projecting bristles, also of protective value. A flea cannot retreat among the fur of its host; it must always advance or jump off at a tangent. The legs are extraordinarily muscular, and useful not only for jumping and holding fast, but for levering the body through narrow passages and crevices. There are piercing and sucking mouth-parts, too intricate for brief description, and there are two

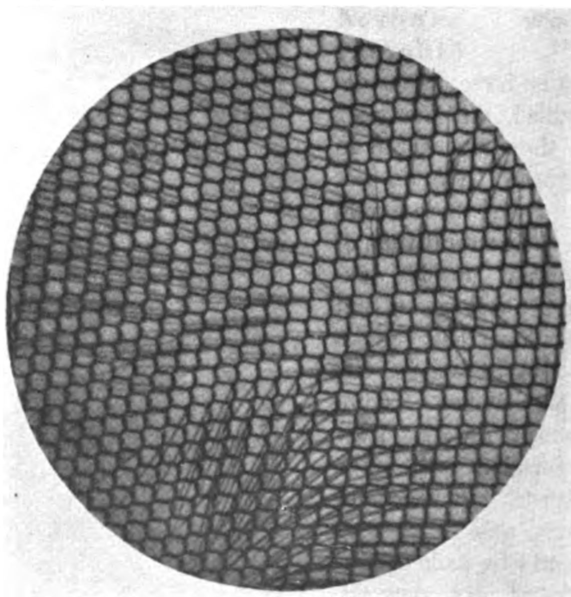
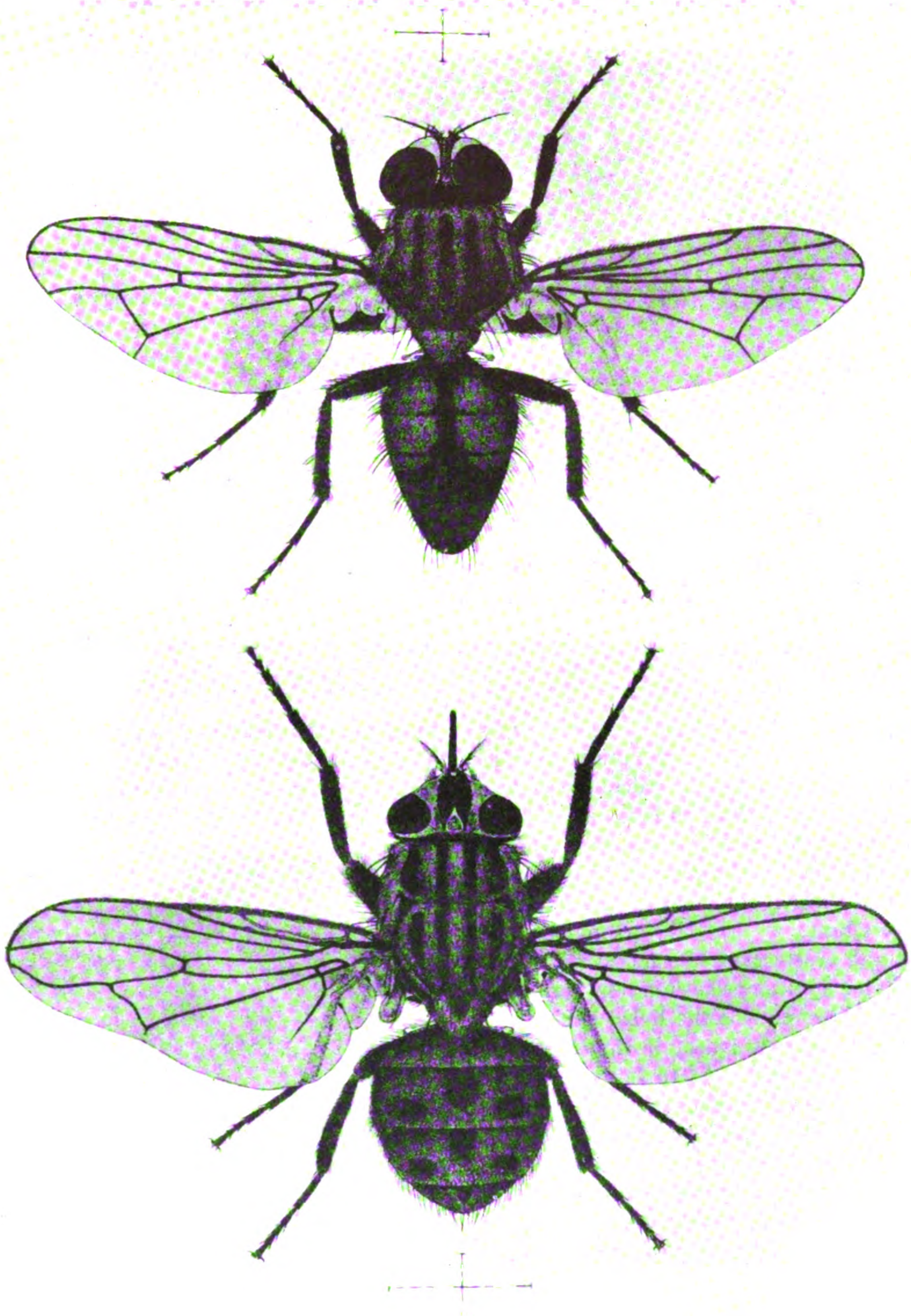


Photo: John J. Ward, F.E.S.

PART OF THE EYE OF A HOUSE-FLY. (Highly magnified.)

The head of a fly bears two large compound eyes with hundreds of lenses. In front of each lens there is a corneal facet, and the hundreds of these give a very characteristic appearance to the surface of the eye. There are also three simple eyes, with one lens each.



Reproduced from "The House-Fly," C. Gordon Hewitt, D.Sc., F.R.S.C., by courtesy of the publishers, the Cambridge University Press.

Top: MALE OF LESSER HOUSE-FLY (*Homalomyia canicularis*), AND Below: FEMALE STABLE-FLY (*Stomoxys calcitrans*).

The smaller or lesser House-fly has a paler and more pointed body than its larger relative. It has more intensely red eyes and is very active in habit. The males predominate. The Stable-fly, that often attacks cattle, is very like the common House-fly, and often comes into houses. It has a hard proboscis, which gives a sharp prick. Compared with the House-fly, it is more distinctly spotted grey and black.

Photo: John J. Ward, F.E.S.

FEMALE COMMON FLEA (*Pulex irritans*). (Highly magnified.)

The shape of the flea's body is very unusual, being flattened from side to side. This is probably suited to the insect's habit of insinuating itself through small crevices. The same may be said in regard to the numerous setæ or stiff hairs on the legs and the back, for they all point away from the head.

could jump, but we have forgotten what he got as answer. We may notice, however, that there is a fallacy in all calculations to the effect that if a flea were as large as a lion it could jump as far as a lion endowed with the energy of a flea. The relation of muscles to skeleton is entirely different in the arthropod and vertebrate types. In arthropods, like insects and crustaceans, the muscles are inside a non-living cuticular skeleton; in vertebrates the muscles are outside the living bones. But this is not the only fallacy in the calculations to which we alluded. As to facts, a flea can jump four inches into the air and about a foot on the level. It is quite far enough.

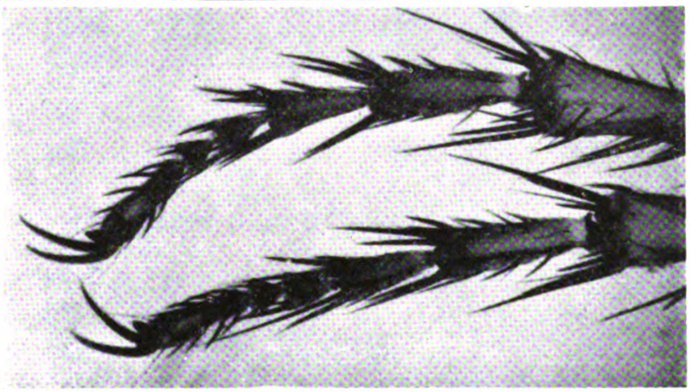
Fleas belong to the higher insects with complete metamorphosis, and are perhaps not very far away from the two-winged flies or Diptera. There are the usual four chapters in the life-history—egg, larva, pupa, and adult. In many cases, as in the fleas of cats and dogs, the eggs are laid in the fur of the bearer, and the larvæ may develop in the sleeping-place. In the case of the common human flea (*Pulex irritans*), which is also found on the badger, the development takes place in dusty crevices, like the joints of flooring. Out of the egg in a few days there emerges a minute whitish legless larva, and it is interesting that the breaking of the egg-shell, as in the chicken, should be effected by a special "tooth," which soon disappears. The larva is an active creature, moving about with the help of its bristles, and searching for organic débris of minute size. Perfect cleanliness is the fundamental counteractive of fleas; it is to the accumulation of crumbs in the wide sense that their multiplication, like that of rats, is due.

After a couple of moults the larval flea falls into the quiescent pupa state. It undergoes the great change which results in the development of the adult insect on an entirely new architectural plan. A very

Photo: John J. Ward, F.E.S.

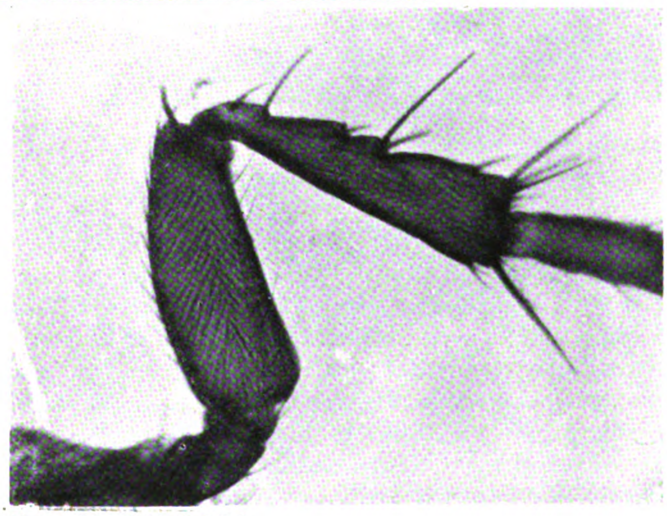
EGGS OF COMMON FLEA (*Pulex irritans*).

The eggs are oval and whitish, slightly adhesive. Their diameters are one-fortieth and one-sixtieth of an inch. They are laid in places where there are accumulations of dirt and dust, such as rugs. Out of the eggs come whitish, wriggling larvæ.



important fact is that the potential flea lies ready made within the cocoon-envelope, resting until some vibration, such as that caused by a human footstep, pulls the trigger of activity. This accounts for the sudden emergence of fleas when we inspect an empty house, or take a drive in a carriage which has not been used for some time. In his admirable British Museum guidebook "Fleas," the most exciting pennyworth we know, Mr. James Waterston, B.D., D.Sc., tells us that the sand-martin's fleas become impatient in their waiting. They have been resting through the winter in the burrows of the migratory birds, but they are restless in spring and hatch out, "congregating in swarms round the entrances of the burrows, where on a fine April morning one may see them waiting for the arrival of visitors." It is an almost idyllic picture—the vigil of the sand-martin's fleas. Pheugh!

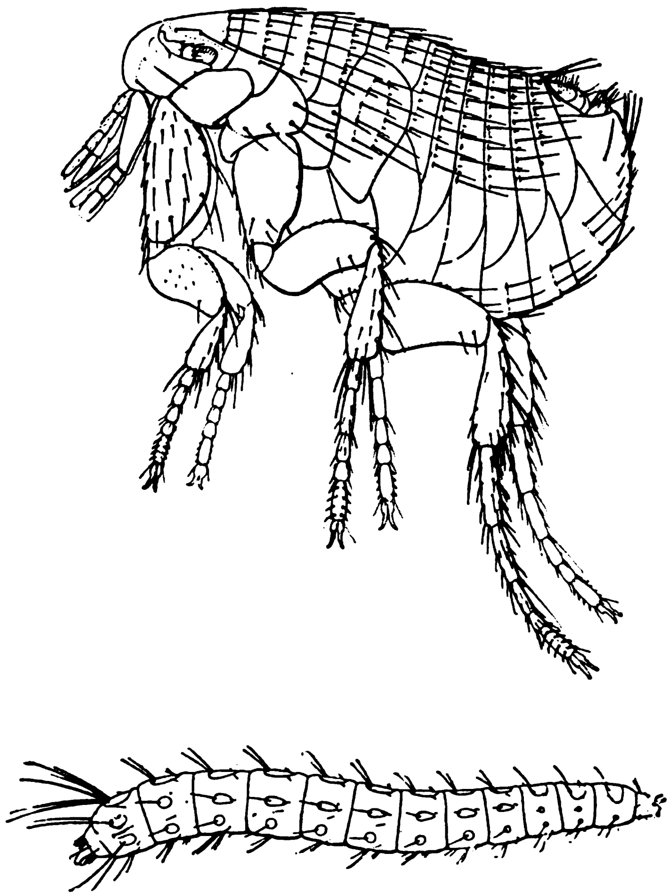
Since an adult flea must have blood for food, one can understand that many must emerge from the pupa-case only to die. No doubt many do. But the full-stop, which is what man desires, is often evaded by the waiting "habit." Moreover, the hungry larvæ have eaten so much in the way of organic dust that the adults emerging from the cocoons are in very good condition, and can dispense with food for several months. The males, who are in a minority, hatch out first. When the females appear, pairing takes place, and fertile eggs will be laid if the female can get an appropriate meal of blood. For bird-fleas do not like mammal's blood, nor mammal-fleas birds' blood. Here—we almost said "providentially"—there is another chance against the completion of the vicious circle. The mother-flea must have her



Photos: John J. Ward, F.E.S.

PARTS OF THE COMMON FLEA. (Highly magnified.)

The top photograph shows two of the flea's mouth-parts, the two mandibles which pierce and the two maxillary palps which feel. The mandibles have two rows of seventy-five minute teeth along each side. There are also maxillæ and a labium. The middle photograph shows the terminal claws and a number of the bristle-bearing joints of the jumping legs. In the lowest photograph are seen some of the jumping muscles shining through the "thigh" joint.



Reproduced by courtesy of the Trustees of the British Museum (from Natural History pamphlet No. 3—" Fleas," by James Waterston, B.D., B.Sc.).

MALE ASIATIC RAT-FLEA (*Xenopsylla cheopis*). THE LARVA BELOW.

This flea is the vehicle of the microbe of the Plague (*Bacillus pestis*). When the flea leaves the dead rat and bites man, the bacillus is launched on a new career. As usual the larva is a whitish, footless, wriggling maggot with many bristles, which help in locomotion. It feeds on dry organic particles and the parasitic life does not begin until the fully formed flea emerges after metamorphosis.

draught of blood, and, in many cases, it must be of a particular brand. One of the outstanding facts of life is specificity.

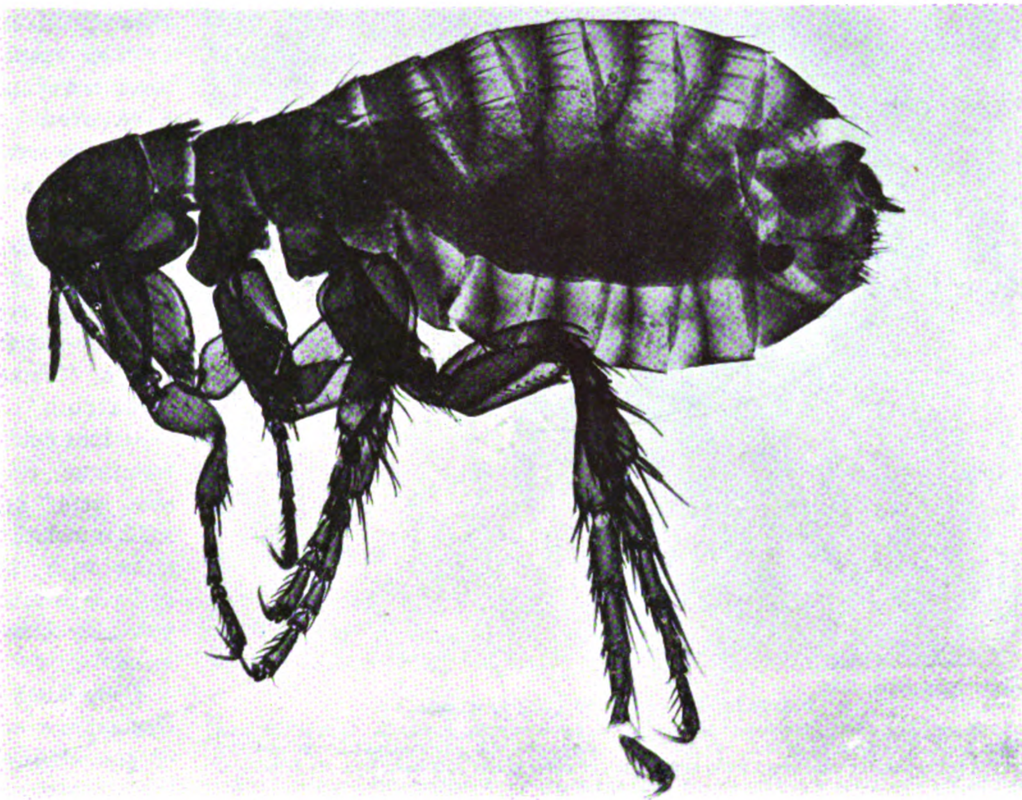
Zoologically regarded, if we can attain to adequate detachment, fleas are admirable. Without wings, which every respectable insect should possess, they are able to pass from man to man along the length of a tramcar. Their muscular explosiveness verges on the miraculous. Dependent on the blood of higher animals, they have (so we think) refused to accept the stigmata of parasitism. With an extraordinarily precarious life-history, they have been able to get the better of a dozen difficulties. To lie waiting till a host passes by is a stroke of genius.

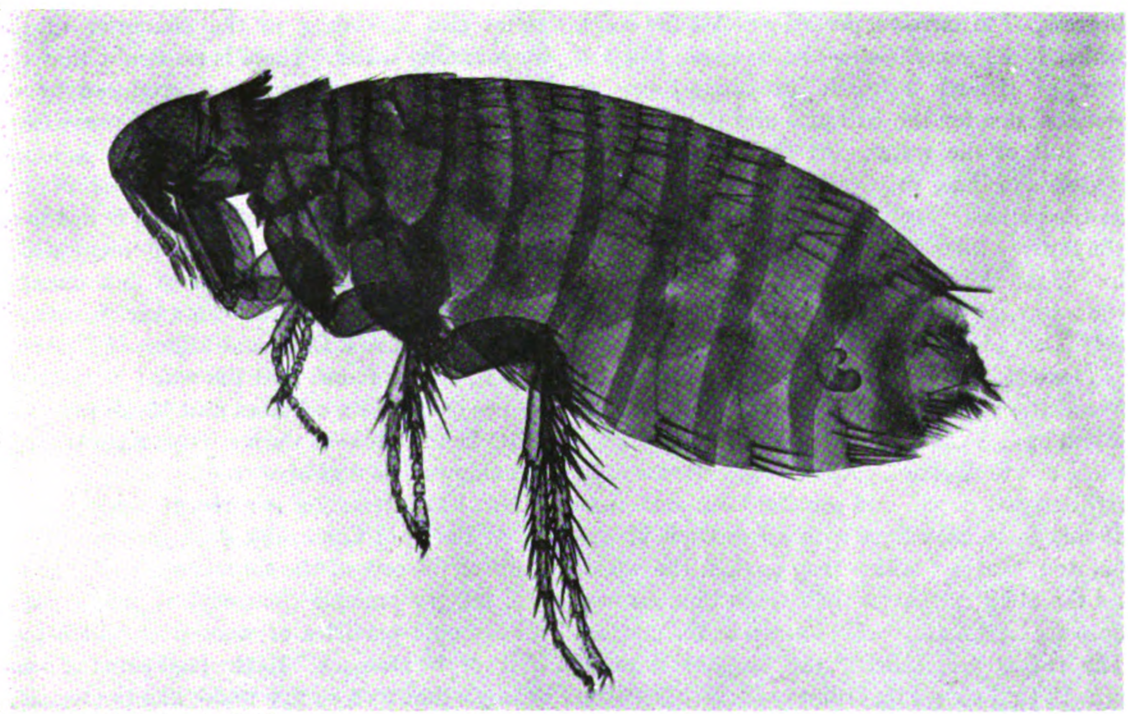
But we cannot remain detached, for the flea is a menace to mankind. A flea is the intermediate host of a tapeworm found both in dog and man. " Much loss is annually caused to poultry rearers in the tropics and certain portions of the United States by the drain on the health of their stock due to a sedentary flea ; and a closely allied species attacks man, causing sores painful, or even crippling, if neglected." But that is as nothing compared with the fact that eleven different kinds of fleas have been proved capable of transmitting the microbe (*Bacillus pestis*) of the Bubonic Plague—the "Black Death" of yore. Between 1896 and 1911 upwards of seven million people died of Bubonic Plague in India alone, mainly through the bite of the rat-flea (*Xenopsylla cheopis*), which transfers the virulent microbe from rat to rat, and from rat to man. As the plague lurks in many of the great ports of the world and is ever blazing out afresh in India, the importance of flea-control and rat-control is obvious. This is but a particular instance of the general fact of the correlation of organisms in the web of life. The flea does not live or die to itself !

Shipworms

We found on the shore a piece of timber about two feet in length, broken off from we know not what, which was traversed by the long burrows of the shipworm or Teredo. Where the interior of the borrow was exposed it was seen to be plastered with a white layer of shell-like secretion, but there was no trace of any animal. Except where some bent outwards to open on the surface, the burrows were all in the same general direction, following the grain of the wood ; but one never broke into another, though the partitions separating them were often thin.

Shipworms are strangely transformed bivalve molluscs, with an elongated body, and the shell-valves reduced to two small boring instruments at the anterior end, which is lowest down in the





Photos: *W. H. S. Cheavin, F.E.S.*

FEMALES OF THE HEDGEHOG FLEA AND THE MOLE FLEA. (Highly magnified.)

One of the many interesting facts about fleas is that particular species are sometimes confined to particular hosts, illustrating the origin of species from isolated varieties. But it is very far from being true that each kind of mammal has its own peculiar flea.

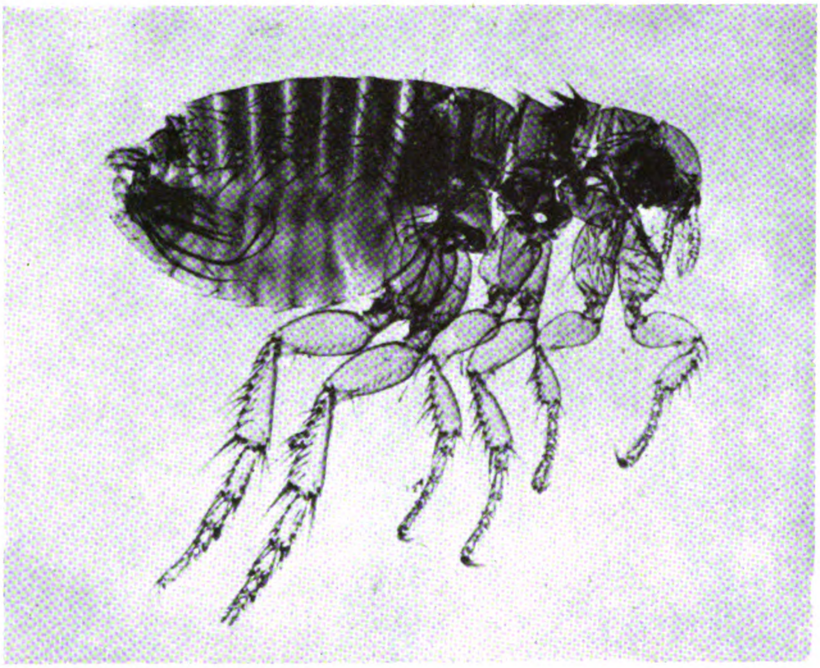


Photo: Hugh Main, B.Sc.

DOG FLEA (*Pulex serraticeps*). (Highly magnified.)

This species of flea infests the dog and also the cat, and some other mammals. It may bite man, but it does not make a habit of it. The photograph shows very well the numerous backward-pointing setæ or bristles on the compressed back, and the strong development of jointed legs. It is believed that the dog's flea is the host of the bladder-worm that becomes a tapeworm in the dog when the flea is swallowed.

burrow. The narrower posterior end of the body, which looks superficially like a worm, bears a pair of slender extensile breathing-tubes or siphons, one for the entrance and the other for the exit of the water. At their base are two platelets of lime, very variable in shape, known as the pallets. Their use is to shut the door of the burrow when the breathing tubes are drawn in. If the shipworms are on the piles of a wharf the water can be retained in the burrow when the tide is very low.

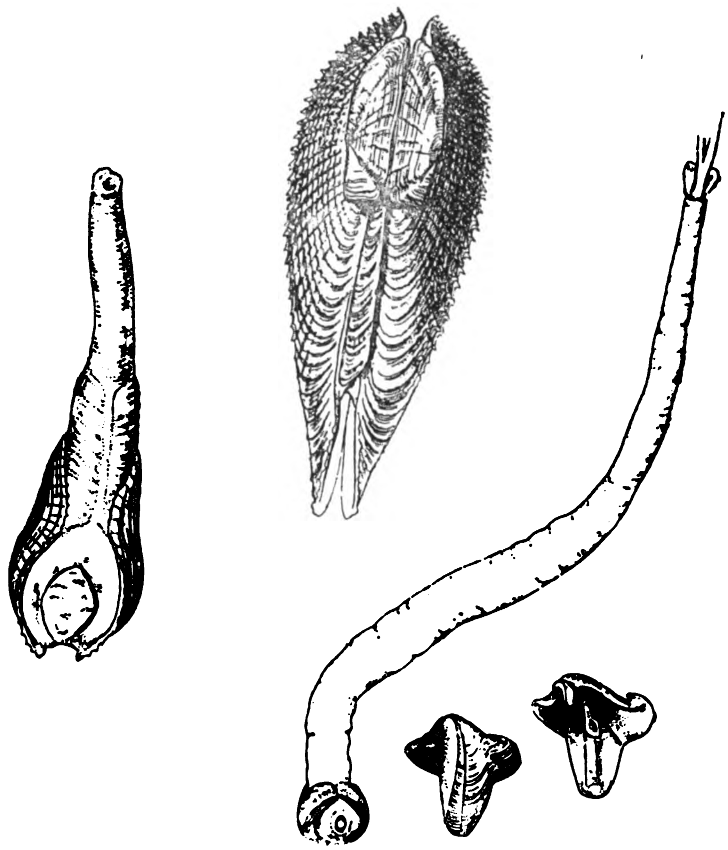
There is no doubt that the boring is effected by a rocking movement of the two shell-valves, which have a peculiar shape, very different from those of a mussel or a cockle. They show a deep right-angled notch, and parallel with the edges of this there are ridges with microscopic sharp-pointed " teeth " which rasp against the wood. As the older ridges get their teeth blunted new ones are continually being formed at the margin. The ridges are, indeed, the familiar lines of growth that we see on ordinary shells. Between the two right-angled notches there protrudes the mollusc's soft " foot," which acts as a sucker, adhering to the wall of the burrow and giving the shell-valves purchase in their rasping. The result is a symmetrically excavated burrow. When the creatures are at work the sound made by the files may be heard, and Dr. Calman, in his British Museum booklet on boring animals, quotes from Moffett's "Insectorum Theatrum" (1634), " Rodunt dentibus, perforantque robora, vel sono teste," or, in Topsell's translation, "They gnaw with their teeth and pierce into okes, as you may know by the noise."

There has been much discussion over the food of the shipworm, and the probability is that it varies at different times and according to the character of the surrounding water. There is no doubt that the animal swallows the sawdust produced by its boring, but this would not in itself prove that it fed on the wood, since rock-dust is found in the food-canal of some relatives of the shipworm that bore in rocks. But it has been shown that the liver contains a ferment which attacks the cellulose of the wood and changes it into sugars and the like. In a recent investigation by Messrs. Dore and Miller, of Berkeley (1923), it was found that the wood loses about 80 per cent. of its cellulose and 15–56 per cent. of its hemi-celluloses during its passage through the shipworm's digestive tract.

Not less interesting is a recent study by Mr. F. A. Potts, of Cambridge (1923), showing that some of the cells of the shipworm's liver behave like hungry amœbæ (phagocytes), and capture microscopic particles of wood-dust which pass in from the stomach. In the food-canal of some animals that feed on dry wood, like the termites or white ants, there are, as we have mentioned, singularly beautiful Protozoa which ingest the wood-particles and change them into sugar.

When the Protozoa die, their stores are at the disposal of their host's food-canal; the sugar is absorbed and partly changed into fat. We have also seen that in some other cases, such as the young stages of death-watches, the food-canal contains yeast-plants which brew the wood. But the shipworm does not have any partner Protozoa or partner yeasts; it has to digest its food for itself. As Mr. Potts says, it has to be its own cook. It is suggested that the hungry amœboid or phagocytic cells that engulf the wood particles and digest them have a very limited length of life, and that they disintegrate, thus liberating the sugar which they contain, and placing it at the disposal of the shipworm's food-canal.

Mr. Potts did not find in the stomach and liver anything but wood, and there were only very occasional diatoms in the intestine. This is against the view of most students of shipworms, for it is generally believed that part of the food consists, as in ordinary bivalves, of microscopic organisms swept in, by ciliary action, along with the water used in respiration. If a little Indian ink is put into the water the particles are soon afterwards found in the food canal and the liver, and the same thing is believed to happen with microscopic drifting organisms. Perhaps the apparent discrepancy may be due to a variability in the shipworm's diet. For a time it may depend wholly on sawdust, and then it may rest from its burrowing and feed on the drifting "plankton." This seems an almost necessary conclusion, for there is in the wood only a very small amount of protein material, and ordinary animals cannot live long without proteins. We adhere, therefore, to the conclusion that the shipworm ekes out the wood dust with a plankton diet, which is of special importance for purposes of growth and repair.



BORING MOLLUSCS, PIDDOCK AND SHIPWORM.
After Gwyn Jeffreys.

The Piddock (*Pholas dactylus*) is able to bore in rocks. The figure to the left shows the muscular foot between the gaping valves, and there is also a long breathing siphon. At the end of the shipworm's long soft tube are seen two breathing siphons and two "pallets." At the boring end are the two relatively small shell-valves, which have been separated off to the right. It is by the movements of these valves that the wood is cut.

The question of the shipworm's diet may seem remote from practical affairs, and yet the reverse is true. The demonstration of the digestion of wood particles shows that the method of soaking the timber with some poison is sound. There is assured intimacy of contact between the poison and the digestive juices. As Messrs. Dore and Miller say, "Digestion of wood constituents by Teredo produces optimum conditions for the absorption of toxic substances contained in the wood."

The practical importance of shipworms was greatly decreased when vessels began to be built of iron and steel, but, in spite of sheathing, scupper-railing, and creosoting, they still do a great deal of damage to the timbers of harbours and the like. We quote a good sentence from Dr. Calman's booklet: "The dreaded shipworm

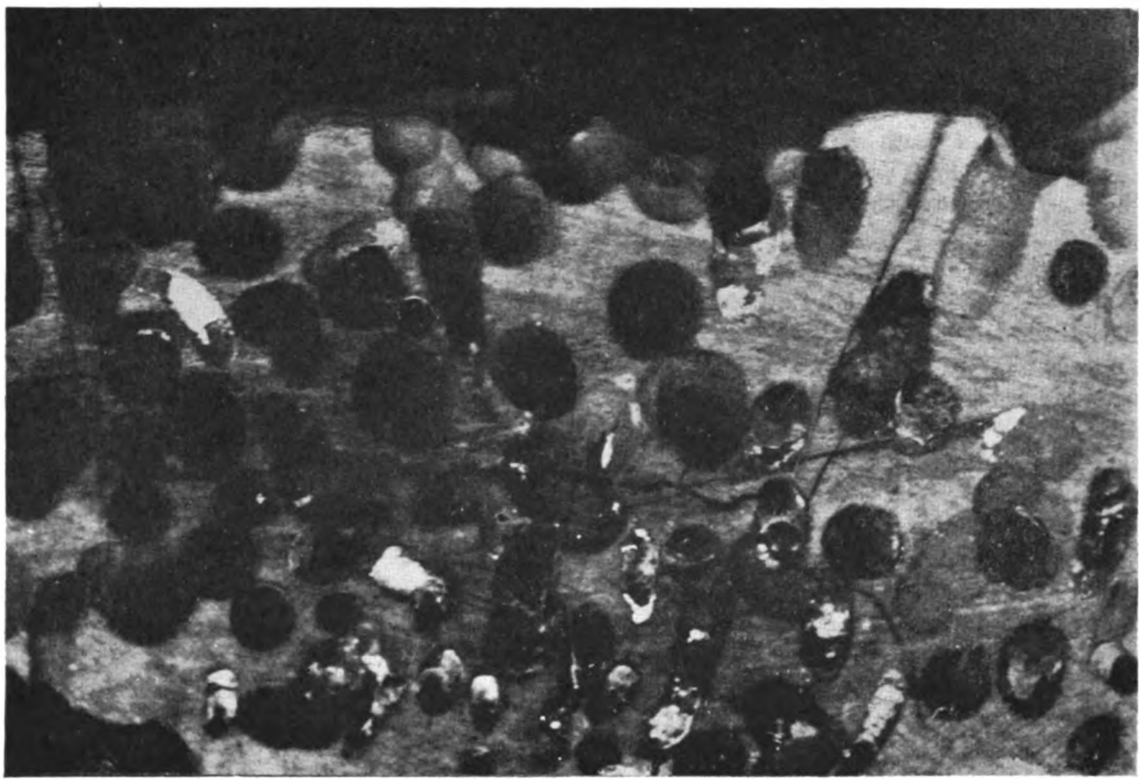


Photo: John J. Ward, F.E.S.

WORK OF A TIMBER-BORING MOLLUSC, THE SHIPWORM (Teredo).

In many cases a big log is so thoroughly riddled with the boring shipworms that there is more to be seen of holes than of wood. A common size of burrow has the diameter of a lead-pencil.

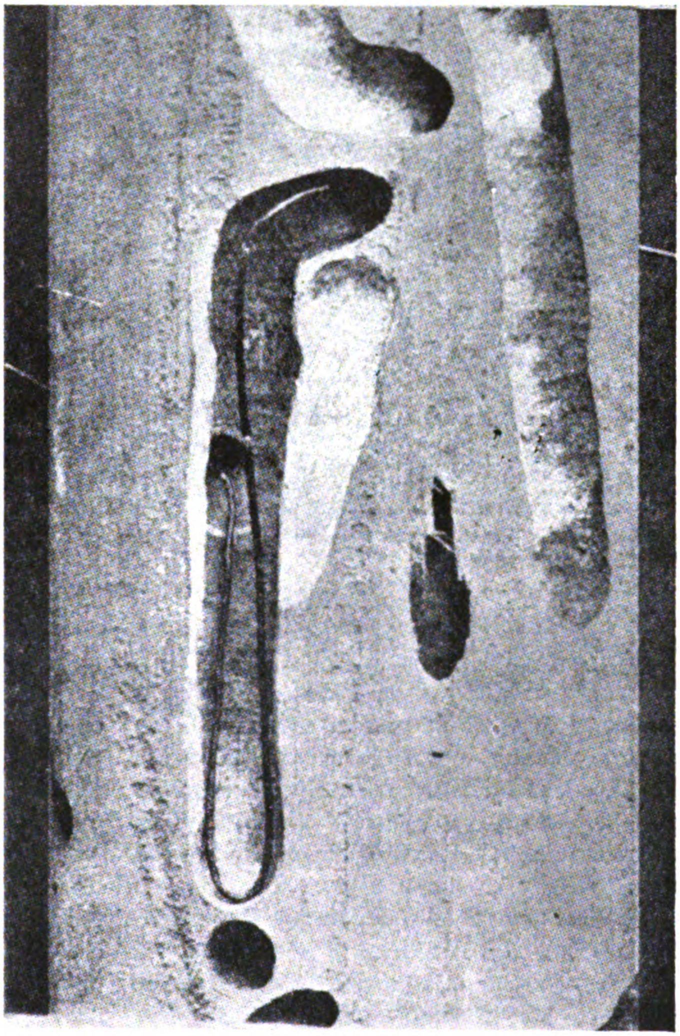
—' calamitas navium ' as Linnæus called it—has been an enemy of seafaring men since ships first sailed the seas; it attacked the triremes of Athens and the galleys of Venice, it rotted the timbers of Drake's *Golden Hind*, and it is causing anxiety in the present-day revival of wooden shipbuilding; in the dykes of Holland it has more than once threatened disaster to a nation; and in many parts of the world it still defies all the resources of the harbour engineer." One of the difficulties in dealing with the shipworm is the minute size of the free-swimming larva when it settles down on the wood and begins to creep about. It may be only a hundredth of an inch in length, and a very minute exposed surface will allow it to begin its perforation. For a long time there may be only a pinhole opening to the hidden burrow. Another feature is the rapidity of growth. Thus Mr. Potts tells us that in twenty-four days a new raft at Samoa was penetrated by burrows containing shipworms that were themselves producing larvæ. In less than three months a box was so much penetrated that all the available wood was used up, and any further burrowing would have meant penetration into neighbouring tunnels. At this point the animals did not simply suspend operations and live on plankton; they died. The rates of growth vary greatly with the species, the wood, and the sea; but a burrow eleven inches long was excavated at Plymouth in thirty-one weeks. A full-grown specimen of the common *Teredo navalis* is from twelve inches to sixteen inches in length, with a burrow about one-fifth of an inch in diameter. The kind known as Xylophaga, which has sometimes done damage to dock gates and harbour timber in this country is recorded as boring into the sheath of submarine telegraph cables, and it is also interesting as a link between the shipworm family (Teredos) and that of the Pholads or piddocks, many of which bore into rocks. The whole story of these boring bivalves is a fine illustration of the intensity of the struggle for existence and on the indomitable will to live.

The life-history is remarkable, almost romantic. In some species the minute and very

numerous eggs pass out by the exhalant breathing tube and are fertilised in the sea. In other species the fertilisation is internal and the eggs develop for a while in the cradle of the gills. A large female Teredo may produce, it is said, a hundred million eggs, and an interesting point is that, in at least some kinds, the young small-sized individuals are males which turn into females when they grow big. Whether the fertilisation be external or internal, the eggs give rise to actively swimming larvæ which may continue to develop in freedom for about a month. Eventually they settle down on wood, but move about on the surface as if seeking for a suitable depression or crevice. They moor themselves with a single glutinous thread and begin to scrape off microscopic particles which are cemented over the minute body. In about two days they begin to sink in, having undergone a considerable transformation, losing the structures suited for free swimming. The larva is only about a hundredth of an inch long when it settles down, but in two weeks it has assumed the characteristic boring form and has increased hundreds of times in volume. In thirty-six days it may be four inches long. Dr. Sigerfoos reports that he took specimens of *Teredo dilatata* four feet long and an inch in diameter at the anterior end from piles that had been in the water less than two years. Indeed these long shipworms were only about a year old—a case of prodigious growth.

There are many different kinds of Teredo, and the genus Bankia has also a world-wide representation. In both cases the boring is due to the rasping of the margins of the shell-valves against the wood. Another genus called Martesia links the worm-like Teredo and Bankia to the commonplace clam type. Its borings are rarely over two and a half inches in depth, and thus there is no need for the body to be drawn out into a long tube. Practically it is of considerable importance because of its relative indifference to creosote. In a few months, we read, it managed to sink a barge built of heavily creosoted lumber.

Some timbers are more resistant than others, but all yield eventually to the persistent borers. Concrete and metal structures are doubtless resistant, but they have their own tendencies to deterioration. There is some efficacy in charring and tarring the outer zone of the piles; and there is even more security in the expensive method of armouring the timber with zinc, copper, or other hard coatings. But the most practicable



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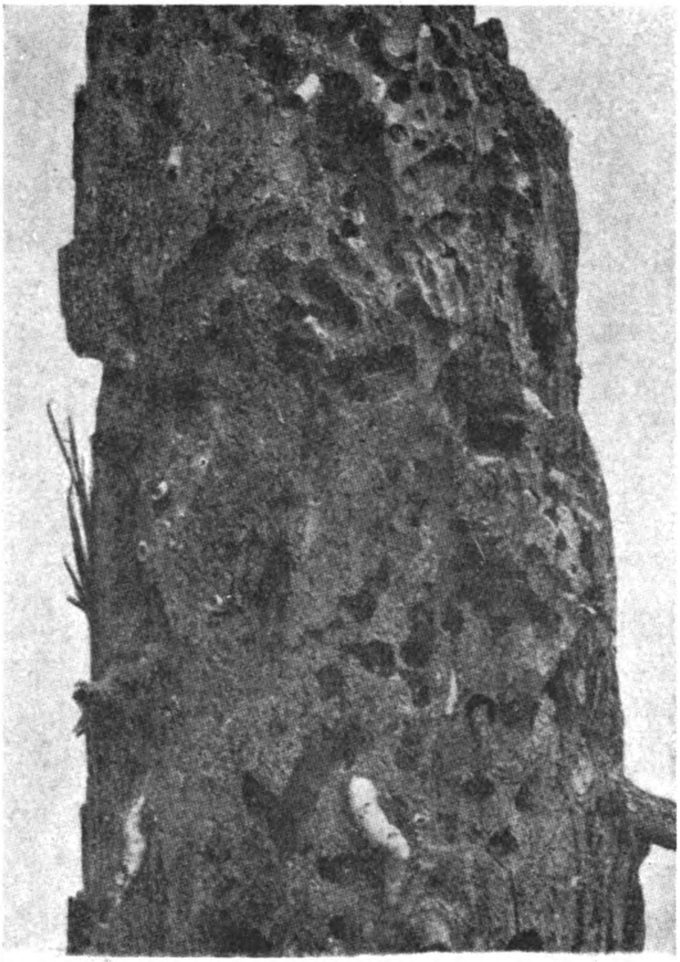
BURROWS OF SHIPWORMS.

Although the burrows made by neighbouring shipworms or Teredos come very close to one another, they seldom encroach. A wire put into one of the burrows in this log of wood shows the change of direction as the burrower approached one of its neighbours.



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PART OF A PILE FROM TORQUAY HARBOUR, ATTACKED BY *Teredo norvegica.*

The surface of the wood has been nibbled away by the boring crustaceans, Limnoria and Chelura, and this has exposed the deeper and quite different burrows of the boring mollusc, in this case *Teredo norvegica.* The lining of the shipworm burrow is glistening white when freshly exposed.

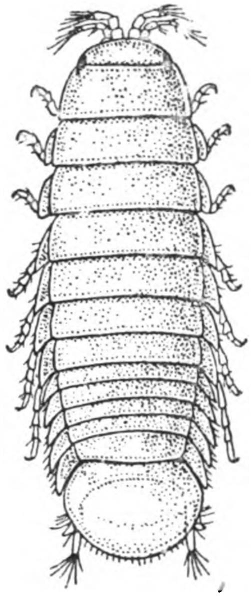
remediary measure at present seems to be to saturate the timber with some toxic substance like arsenious oxide. which may very profitably have creosote as its vehicle or medium. The borers are not easily baffled, but poison is a full stop.

What we are trying to illustrate is the variety of ways in which the circle of human life and human interests is intersected by the life-circles of other organisms, sometimes for good and sometimes for ill. One of the intersections on the minus side that has been attracting much attention recently is the destructive activity of marine borers that attack wooden piles along the coasts. A thorough investigation of cause and cure has been in progress for some time in the United States, and an excellent report by Atwood and Johnson has been published by the National Research Council (1924). The problem is in many places of great importance where there are long stretches of unprotected wooden piles. It is of special interest to harbour engineers and their clients.

Other Timber Borers.

So far as timber is concerned, there are two chief kinds of destructive marine borers—namely, molluscs and crustaceans—and they have very different ways of working. The mollusc borers, like the shipworm which we have already discussed, enter the wood when they are young and small, and enlarge their burrows as they grow. Thus the interior of the timber may be honeycombed without there being much external indication of what has happened, for the entrance apertures are minute and readily overlooked. The wood-boring crustaceans, on the other hand, make shallow galleries just beneath the surface, and often occur in such huge numbers (e.g., two hundred to the square inch!) that the outer zone of the timber breaks off altogether, exposing a new surface to attack. Thus the crustacean borers are much less insidious than the molluscs; one can see what they are doing. They also work more slowly, for "under conditions conducive to the greatest activity the molluscan borers may destroy a fourteen-inch pile in a few months, while the crustacean borers have not been known to do this in less than a year."

The most important crustacean timber-borers are species of the genera Limnoria, Chelura, and Sphaeroma. The first and third of these (we have put them in order of importance) belong to the Isopod order of "slaters" or wood-lice, and have somewhat slipper-like bodies, flattened from above downwards. The second borer, Chelura, belongs to the sandhopper or Amphipod order, with the body flattened from side to side.



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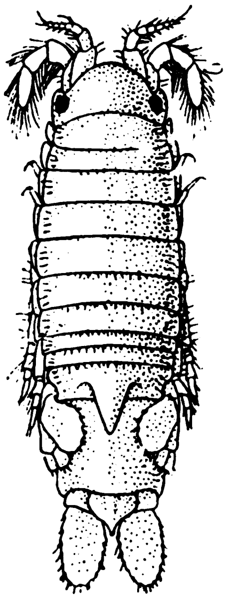

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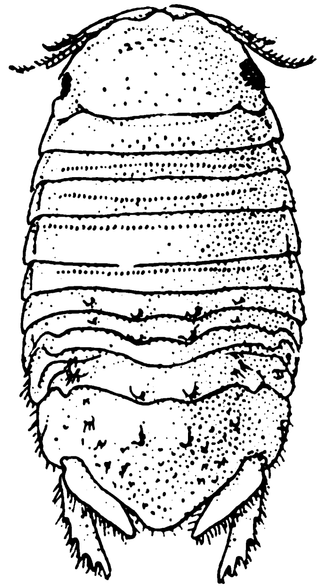

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1. LIMNORIA LIGNORUM. Enlarged (after Sars). A flattened Isopod Crustacean that does much harm by devouring and disintegrating the wood of harbour-piles and the like.

2. CHELURA TEREBRANS. Female. Enlarged (after Sars). The male differs in having much longer tail appendages (uropods) and dorsal spine. An Isopod Crustacean that nibbles at wood and similar substances and can give a good account of itself as a burrower. There are considerable differences between the sexes.

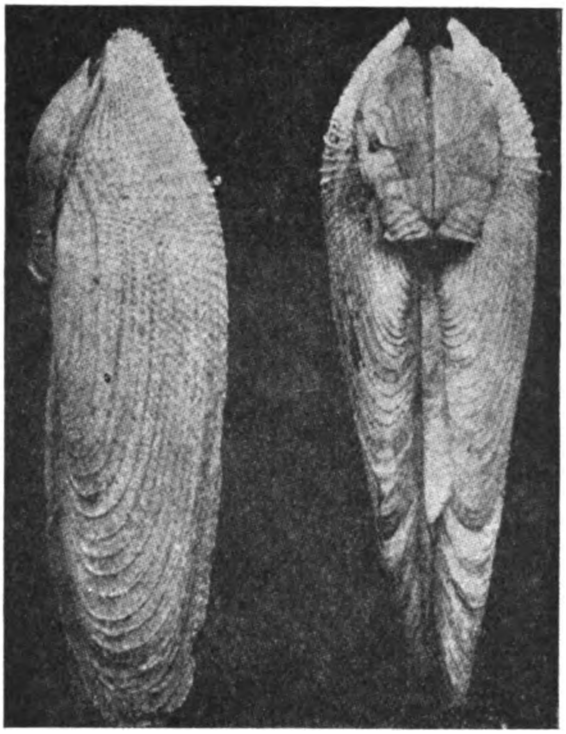
3. SPHAEROMA TEREBRANS. Enlarged. A flattened, broad-bodied, Isopod Crustacean, often found among decaying material, and sometimes a genuine burrower.

The most familiar of these crustacean borers is the gribble (*Limnoria lignorum*), which gave Robert Stevenson considerable trouble when he was building the Bell Rock Lighthouse, more than a hundred years ago. It is a woodlouse-like animal one-eighth to one-quarter of an inch in length, with nineteen pairs of appendages, including seven pairs of clawed walking-legs by which it creeps in its burrow, and a pair of stout jaws that do most of the boring. It is a hardy animal, with a wide geographical distribution. The burrows often run along the softer early summer wood, but they also interlace irregularly. A common diameter is about a twentieth of an inch, and it is uniform for each size of animal. There may be 300 to 400 gribbles of all ages in a single square inch of wood, and naturally enough that area of wood does not last long. The young ones are miniatures of the parents when they hatch out of the six to seventeen eggs that are sheltered in a brood-pouch between the legs on the underside of the female, and they are able to bore from the very first. Although the crustacean borers usually work just below the surface, this is impracticable when the wood is well creosoted. In such cases the gribble "frequently gains an entrance at a knot, abrasion, or other point of thin treatment, and works inwards until it reaches the untreated centre. This portion of the timber is promptly destroyed, and the outer treated shell left intact."

Enthusiasm for slugs and snails is perhaps an acquired taste but there is no denying their interest. They are among the highest backboneless animals, and they are not tyrannised over by instincts like ants, bees, and wasps that are always being cracked up to us. We have already referred to Darwin's pleasant story about two snails that found themselves in a very inhospitable garden. So one of them, with more vigour than the other, went exploring over the wall and found a land of plenty. What did it do but retrace its steps to its companion, to whom it somehow or other told the good news. Then the two of them set out together over the garden wall. Had not the first snail memory as well as morals?

Slugs and Snails.

An American lady taught a snail to form an association. When she touched its lips with a tit-bit it not unnaturally made munching



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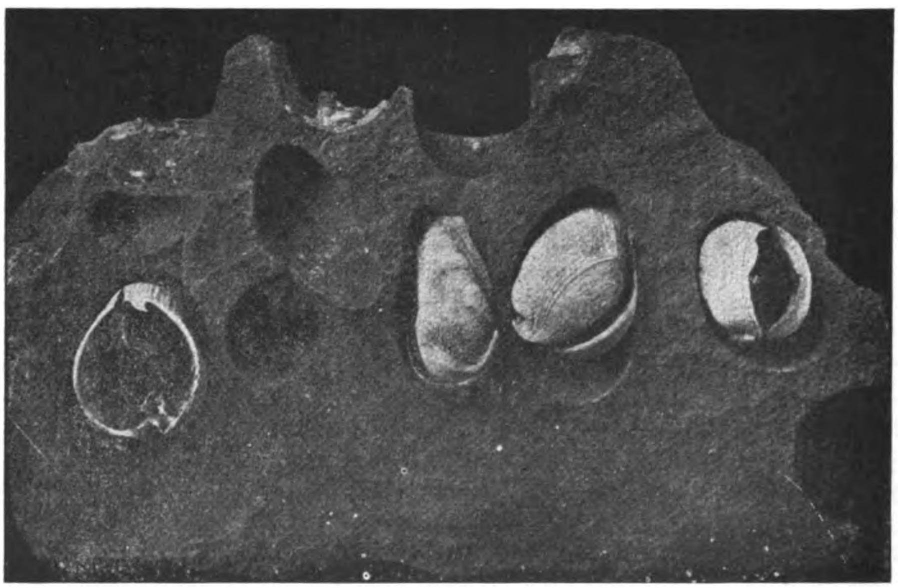
SHELL OF THE BORING PIDDOCK (*Pholas dactylus*).

The right-hand figure shows the dorsal surface of the shell of this boring bivalve and the presence of several extra platelets between the valves. The left-hand figure is a side-view, and shows rows of sharp, rasping teeth on the shell.

their everyday life. This is particularly advantageous for those that confine themselves to special kinds of food, such as mushrooms. They know them at a touch.

Some years, when there is much wet weather, there are multitudes of black slugs. What handsome fellows they are, with their finely ridged and wrinkled skin, usually like black velvet, but of almost any colour when they are young. There is often a red seam at the junction of the cylindrical body with the flat creeping sole. When we watch them we see the large breathing aperture on the right side, leading into a sort of lung; the two pairs of sensitive horns, the longer with eyes at the tip; the exudation of a special slime gland at the hind end. This special gland is absent in the Grey Slugs (Limax), which also differ in having a remnant of a shell hidden beneath the skin. It is interesting to make an evolution-series; an ordinary snail (Helix) lives in a strong spiral shell; the carnivorous slug (Testacella), which persecutes earthworms ferociously, has a small external shell, a platelet with the merest hint of a spire; the grey slug has a tiny hidden platelet of lime; but in the Black Slug the reduction has been carried further, and all that is left of the shell is in the form of scattered granules of lime below the skin. The popular

movements. But at the same time she touched its head with a glass rod and she continued doing this patiently till the snail learned to make the munching movements when there was no touch of food but only a touch of glass. This was a water-snail, we admit, but all snails and slugs have this degree of educability, and it plays an important part in



PIDDOCKS BORING IN ROCKS.

It is remarkable that these bivalves, which have not strong shells, should be able to burrow into very hard rocks. Innumerable minute movements of the shell and the foot seem to wear the stones in the course of time. The Piddock is one of the luminescent animals. A ferment, luciferase, oxidises luciferin, and light results.

error dies hard that slugs are snails that have crept out of their shells for the summer!

We must always call a slug or a snail "it"; for the creature is male and female by turns. Most of the Helixes have arrows of lime which they jerk out at one another—strange Cupid's darts! The eggs of slugs are clear spheres, usually laid in the ground; those of Helix have delicate shells of lime, and some of the huge land-snails of warm countries have enshelled eggs as large as a sparrow's. What comes out of the egg is in all cases a miniature of the adult—a good example of the way in which larval stages, such as we find in fresh-water snails and sea snails, may be suppressed. In adaptation to the terrestrial life, there has been a telescoping of the juvenile stages, so that what leaves the egg is able to fend for itself from the very start.

Photo: John J. Ward, F.E.S.

BLACK SLUG (*Arion ater*) CREEPING OVER A ROCK.

This handsome slug may reach a length of four inches. Its commonest colour is black, but it may be brown, red, or yellow. The shell is represented by a few particles of lime under the shield or "mantle," on the dorsal surface behind the breathing aperture.

Life often seems a very delicate kind of activity. A tap on the animal's head and it is all over. A gust and the flickering flame is out. On the other hand, what often impresses us is life's toughness, its power of persistence, we may almost say doggedness. We are thinking not of Californian "Big Trees," living on and on for two thousand years, but rather, for the moment, of snails' horns. Each horn has a glistening eye at its tip, which can be withdrawn right into the interior of the head, just as if a glove finger with an elastic band attached internally to its tip, were retracted into the palm portion of the glove. Now, if a snail's horn be cut off—it has been done so shamelessly often that it need never be done again—it is replaced by a new growth from the stump—eye and all, and in no makeshift fashion.

Photo: E. Step, F.L.S.

CARNIVOROUS SLUGS (*Testacella haliotidea*).

Most slugs are vegetarian, but Testacella preys on earthworms and on smaller slugs. It lives mostly underground, and has a yellowish-brown colour. The body shows two conspicuous grooves for exuding slime, and the narrower end is in front.

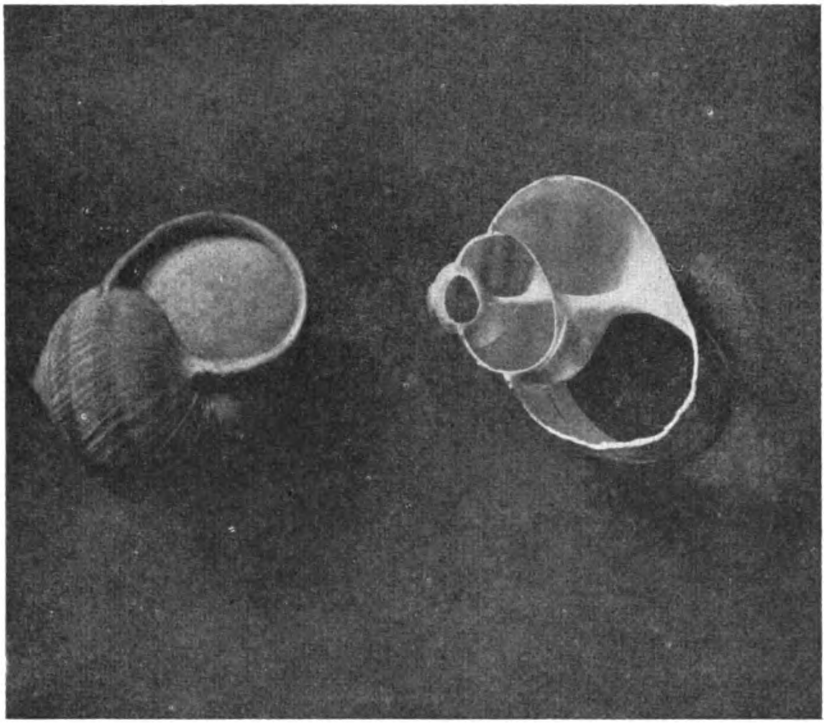


Photo: E. Step, F.L.S.

ROMAN SNAIL (*Helix pomatia*) AND SECTION OF ITS SHELL.

The photograph to the left shows the snail in its winter quiescence, with the mouth of the shell all but closed with a lid (or epiphragm) of lime and hardened slime. The other figure shows the beautiful spiral staircase of the shell, which has been gradually added to as growth continued.

But it is pleasanter to think of the snail's power of persistence in natural conditions. When winter comes, it snuggles into a cranny in the wall, closes its shell with a door of lime and slime, sinks into lethargy and waits for the spring. The Black Slug has no shell, but it contracts into a helmet shape in a secluded corner. "Reculer pour mieux sauter"—that is the slug's policy.

Cobwebs

As an example of an animal that flourishes under the shelter of man's shield we take the House Spider (*Tegenaria domestica*)—the maker of cobwebs. We have been watching a cobweb for months and nothing has happened. We think that the spinster must be dead, for it has been a cold winter, and the window of the room is often open for hours. There are probably some young ones hidden away in crevices, spending the winter in a state of lethargy. Perhaps the mother is also in hiding, waiting with eerie patience, after the manner of many other animals, for the return of warmer weather and small insects. The room is very clean, but many midges and the like come in throughout the summer, the most unwelcome being a small dark-coloured mosquito that makes a very irritating wound. We got one to identify from a minister of the Church of Scotland, and the pill-box in which it arrived was labelled " The Devil." So we are not sorry to see a few cobwebs in the room, and for several years we have had the company of a pair of large house-spiders. She is over three-fifths of an inch in body-length, not counting the legs ; he is well under the half-inch and much slimmer. The general colour is ochreous yellow, but there is a pattern in brown. In the case of the female, at least, the duration

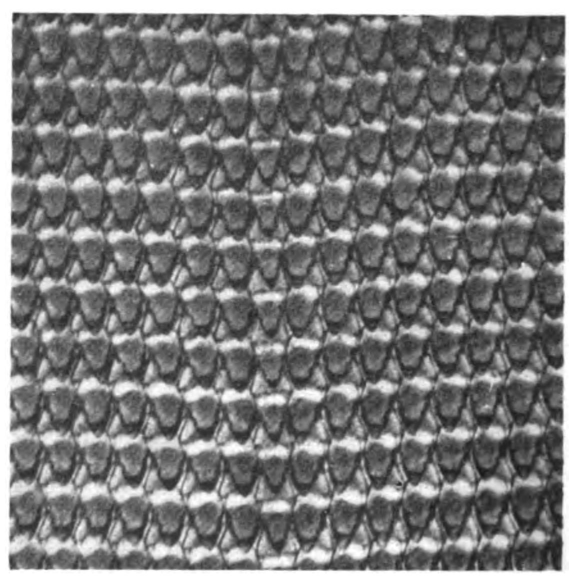


Photo: John J. Ward, F.E.S.

TEETH OF THE SNAIL'S RASPING RIBBON. (Highly magnified.)

On the floor of the mouth of snails there is a flexible file—the radula. It bears row after row of hard teeth, and it can be protruded and retracted by muscles. It forms an instrument for rasping through leaves and the like. Every kind of snail has its own particular pattern of tooth arrangement.

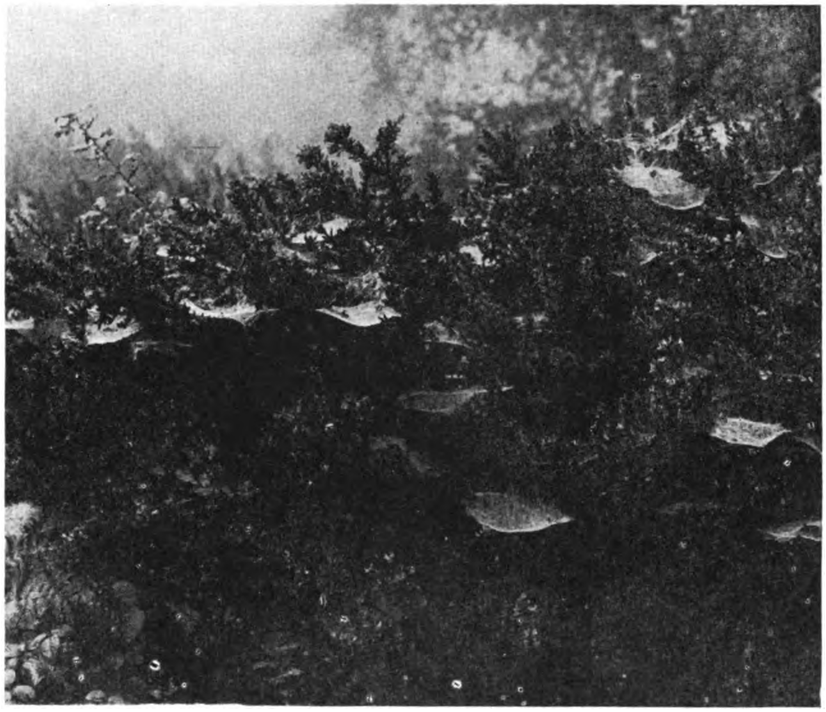


Photo: John J. Ward, F.E.S.

SPIDERS' WEBS AMONG DENSE HERBAGE AND FERNS.

Some of the true webs, with distinctive patterns, are vertical, as in the case of the Common Garden Spider. Others, as in the beautiful photograph above, are horizontally disposed. Others again are in the form of domes kept taut by an external framework of threads.

of life may be four years, so it may have been the same spinner that we have watched for years. As far as we know, the male does not make a web, though there are often three webs in the room. As we have never seen more than the two spiders, we believe that in days of plenty a single female may weave several webs. It is well known that when food is scarce the supply of silk dwindles, and the spider may not have enough even to keep the web in good repair.

As we have already noticed, some spiders do not make any web, but all have the habit of paying out a "drag-line" of silk when circumstances are critical. Thus the Jumping Spiders, which pounce upon their victims, fix the end of a drag-line just as they spring off, thus safe-guarding themselves against a bad fall. If we suppose a drag-line to form a tangle among the grass and herbage, we have the first step in the evolution of a snare. The cobweb is a second stage, where there is a sheet of silk threads, but no particular architecture. In the intricate webs of the Garden Spider there is the evolutionary climax, a maximum of efficiency combined with a maximum of beauty. And just as there are several different kinds of irregular snares or tangles, so there are different grades of cobwebs and of true webs.

A corner is the favourite place for the cobweb spider's operations, or some re-entrant angle across which a horizontal sheet can be stretched. She fixes a thread on one side, perhaps a couple of inches from the innermost corner; she walks round to the opposite side, holding out the thread as she pays it out and keeping it from entanglement; she then pulls the line taut across the corner. It is the outermost line of the future sheet, and it can be made particularly strong by repeating the process and binding several lines together.

Continuing her work, the spider draws line after line from one side to the other, and as the hammock becomes stronger and the lines shorter, she does not need to walk round the wall, she can cross by her own bridge. Finally, in the innermost corner she makes a tubular resting-place, open at both ends, in which she lurks and into which she drags the victims that become entangled on the concave upper surface of the cobweb. The spider prefers a site where the inner end of the tube leads into some cave or crevice which can serve as a final retreat; but this is not essential, for in connection with the cobweb in our room we see no trace of any hole.

The common House Spider has six spinnerets, which are transformed abdominal limbs, and each is like the rose of a watering can, covered with minute tubes or spinning-spools, out of which there comes the multiple jet of liquid silk, hardening instantaneously on exposure to the air. Each spinning-spool is the opening of a duct from a syringe-like internal silk-gland, and the thickness of the thread will vary according

Photo: E. J. Bedford.

A SPIDER'S SNARE AMONG WOOD-SEDGE.

It may be convenient to keep the term "web" for a well-constructed arrangement with a definite pattern, using the term "cobweb" for a sheet that is used in insect-catching, yet has no distinctive pattern. Then the word "snare" may be used for a simpler construction, little more than an elaborate tangle of silk threads.

are eight in number and very short-sighted. She lays many eggs, perhaps sixty in a batch, and these are carefully surrounded by a bag of silk, the outside of which may be very inconspicuous because of entangled fragments of plaster and dust. There must be great juvenile mortality.

House-Spiders, like their kindred, appear to be very sensitive to vibrations and to changes of weather. Whether they can hear in our sense of the word we do not know, for the stories of their fondness for music are of an anecdotal order. There was, for instance, young Beethoven's spider, which used to lower itself on his violin as he played. His mother, disapproving of the companionship, killed the spider, whereupon Ludwig broke his instrument. In after years he denied the tale, adding that everything, even flies and spiders, would at that stage have fled before his terrible scratching. But the spider's world is very largely a world of tremors and vibrations.

to the number of glands that are activated. The common House Spider has actually 360 spinning spools. There does not seem to be any appreciable stickiness in the fine silk threads. If cobweb is used for staunching blood, as Bottom used it, then it should be a clean open-air cobweb like that made by the Labyrinthine Spider among the grass—a "cobweb dew-be-diamoned."

As is usual among spiders, the relation between the sexes appears to be what people call "difficult." The male finds it hard to persuade the female to give him due attention, and they sometimes come to blows. We suspect that he steals food from her web, and this will not recommend him in her eyes, which, by the way,

We have often saved our spider's life, remembering the adage, "If you wish to live and thrive, let the spider run alive." It comes about in this way, that the spider likes a drink, and lowers herself into the wash-basin, the walls of which happen to be vertical. It is easy to get in, and she enjoys the droplets on the sides and floor of the basin, but it is very difficult to get out. Over and over again we have lifted her, but she has shown no reciprocity. She is not like the spider that Christian II of Denmark made a friend of in his prison, which used to come when

he called. The only advance our spider ever makes is to lower herself from the ceiling towards our prostrate form in bed. There in the morning light she dangles between heaven and earth, sometimes pausing, sometimes sinking nearer. But just as we are thinking that she wishes to say " Thank you," she changes her mind and climbs up the rope-ladder again, coiling it deftly as she ascends, so that there is no trace left of her escapade. A neater trick you never saw.

The Case against the Kea

As a puzzling and dramatic instance of the way in which animals may unexpectedly work against man's interests, let us take the story of the Kea Parrot of New Zealand. It is a very difficult case, and of great biological interest, bearing, as it does, on the question of the transmissibility of bad habits. We meet people who have been in New Zealand and are convinced of the Kea's guilt. There is no doubt, they say, that this insectivorous and frugivorous mountain parrot has learned, since sheep-runs began in New Zealand, the pleasures of carnivorous diet. It chivvies the sheep and lights upon their loins. It holds on with its upper beak and digs with its lower jaw; it tears through the fleece and the skin; it pierces to the kidney-fat, for the sake of which it risks its life. It is a gregarious parrot, and in some places a company of them will account for half a dozen sheep in a night. Some sheep ranches have had to be abandoned; the parrots have been seen in the vicinity of dead sheep; queer holes have been found in the sheep's back; and how can one have any doubts at all when the Government has put a price on the Kea's head, and actually paid for 3,584 beaks in 1923! The last piece of evidence must be quite conclusive, for why would the Government pay out this money if the Kea was not guilty? Besides, as a New Zealander said, " I've shot five parrots myself."

There is nothing impossible about the charge against the Kea, for several cases are known of a rapid change of diet among birds. We know, for instance, how the Herring Gull, pre-eminently a fish-eater and a devourer of the wastage of the sea, has become fond of gouging out turnips, pecking potatoes to pieces, and despoiling the stocks in the harvest-field. But for a parrot to attack living sheep and vivisect them, why, it gives one pause. And if it be said that the bad habit began in a small way through the Kea pecking at pieces of fat on the sheepskins hanging outside the country stations, well, the theory seems almost as ingenious as the parrot. Another theory is that the Kea began by mistaking the sheep for a big tussocky cushion-composite, such as it is said to tear at in search of insects; but this comes perilously near contempt of court.

Another line of argument is to inquire into the Kea's character. Is sheep-killing what one would expect from the prisoner's antecedents? In answer to this question it is pointed out that the Kea has unbounded inquisitiveness, and this is a quality that often leads to evil; that it is very " familiar " and mischievous; and that it is a nuisance in the neighbourhood of camps because of its thievish propensities. We do not know that its melancholy cry, " Kea, kea," has been interpreted as indicative of a guilty conscience, but we have heard it said that you have only to look at its strong, curved beak to recognise its sinister possibilities.

More to the point, perhaps, is an inquiry into the bird's feeding habits; for one would, of course, have to acquit a humming-bird charged with killing bees or destroying fruit. But the case of the Herring Gull already mentioned shows how careful one must be in arguing from the past to the present in a world where evolution is still going on. As a matter of fact, the Kea has a long bill of fare. It likes fruit and honey, seeds and grubs. It will condescend to roots and lichen. Its home is characteristically in the mountains of the South Island, sometimes in the open country above the bush line, sometimes in the forests. Although a strong flier, it does not seem to range over a wide area, but bad weather will drive it from the heights to the low grounds. This might bring it into places where its natural food was not available, where vagaries such as sheep-killing might be suggested by the spur of hunger. But the edge is taken off this plausible idea by the great diversity of the Kea's natural vegetarian and frugivorous diet. It cracks seeds, it munches berries, it pecks out grubs, it sucks nectar, it splits pithy stalks, it digs up roots—why should it risk its life for tit-bits of kidney fat? The fact is that

the *a priori* evidence, or presumptive evidence, as the lawyers call it, is neither here nor there. That the bird is sometimes a thief does not prove it a murderer, and its appreciation of maggots does not prove that it is addicted to mutton.

But there lay the dead sheep with queer holes in their loins, and there were the gay parrots in their olive-green costume, faced with black, and touched-up blue, yellow, and scarlet, flying about nonchalantly and screaming " kea." It must have been the parrots that killed the sheep, just as the golden eagles drive deer over precipices and vultures carry off children in their talons. So the fama arose, and grew like " Russian scandal," becoming more and more picturesque, " till not a popular natural history could be published without a reference to the mountain parrot of New Zealand and its unparalleled change of diet from grubs and berries to live sheep; until not a museum in the Dominion was complete without a caricature of a mangled sheep with sealing-wax blood, and a stuffed specimen of the unholy bird engaged in its feast." So writes Mr. J. G. Myers, in an article in a recent number of the New Zealand " Journal of Agriculture," an article which shows this at least, that the case against the Kea is not yet scientifically ended, though the Government continues to subsidise the bird's destruction. Perhaps the verdict will eventually go against the Kea, but the evidence seems to be much less convincing than most of us supposed.

It is an astounding fact, vouched for by Mr. Myers, that " up to 1907 there was not a single recorded case of a witness who had actually seen a Kea attacking a sheep. Nevertheless the statement was circulated throughout the world, received general credence, and in New Zealand became an article of national faith." A careful observer, Dr. L. Cockayne, declared in 1899, in a paper read before the Philosophical Institute of Canterbury: " I have never seen it attack sheep, nor have I met with anyone—shepherd, musterer, or mountain traveller—who has done so; the most that my inquiries have elicited is that sheep are found from time to time with holes in their backs, and that Keas have been seen hovering round sheep." Man loves the anomalous, and the sheep-killing habits of the Kea were accepted as proven.

The case against the Kea has been stated with care in two papers published in 1907 by Professor W. B. Benham and by Mr. G. R. Marriner, the first referring to ten eye-witnesses and the second to over thirty. But neither of these inquirers seem to have actually observed the Kea at work. After studying all the evidence, Marriner said: " Reckoning over the whole Kea country, I am certain that five per cent. of the flocks would well cover the annual loss due to Keas." It seems quite plain that the story of the bird's depredations has been greatly exaggerated, and that the proportion of Keas that take to sheep-killing (like man-eating tigers) is, to say the most, very small.

But why, it may be asked, does not some naturalist shoot a Kea found in the vicinity of dead sheep and examine its stomach? This has been done, and the sheep's flesh has been found in some cases. But this is no proof that the sheep were killed by the parrots. That the Kea may settle on sheep that have died through natural causes is admitted, but Mr. Myers will not say more than that Keas occasionally attack living sheep, and may possibly kill a few. " The strongest proof against the Kea lies in the occurrence of very peculiar wounds in the neighbourhood of the sheep's loins. Such wounds have been found only in Kea country, and can hardly have been produced by any other agency than Keas." Yet this does not prove that Keas kill sheep, for the wounds may have been made after death. And as to the photograph of a living sheep with a hole in its loins and a kidney exposed, this may have been due to a motor car. Yet is it not the case that our uncle in New Zealand had an experienced shepherd whose brother saw the Kea killing a sheep? Perhaps this *was* one of the few cases that may have occurred; yet it was the same man who saw the mother snake saving her brood from destruction by swallowing them! So, long live the Kea!

LXVII

THE ACTIVITIES OF THE ANIMAL BODY

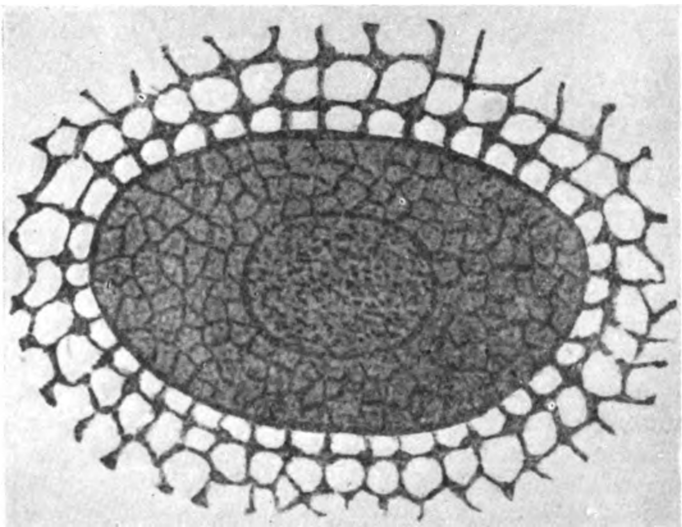
§ 1

THE FUNDAMENTAL CHEMICAL PROCESSES IN LIFE

THE story of the study of the animal body is the story of all the sciences: it tells of each generation of thought looking more and more closely, scrutinising in ever greater detail, in the hope of deepening and clarifying our knowledge of the whole. It is the story of the slow change of an outline sketch into a glowing picture, not yet finished but greatly enriched; to which, we may fancifully say, chemistry has lent its dyes and physics its knowledge of action, and many another science has contributed. It is far over 2,000 years since Aristotle took the first effective step in this process of subdivision, in recognising and studying the various *organs* of the body: and science had to wait almost till the nineteenth century before another stage was reached, and the *tissues* of which the organs are composed were separated and distinguished. In the middle of that century the work of Schwann and Schleiden showed that all living tissues—plant or animal—were composed of *cells*, and another milestone was passed. In the sister science of Physiology, which is concerned with the working of the animal machine rather than with its form, the same sequence is observed; since the days of Harvey, who discovered the circulation of the blood, it has turned from organ to tissue, from tissue to cell; yet it has never forgotten to use each new and more accurate unit for the reckoning-up of the functions of the whole.

Simple Cells.

The simplest animals are not divided into cells; and though many are complex, others, like the Amœba, may be regarded as the type of simple unspecialised cells. There are cells very like them in our blood (phagocytes): moving, changing shape, engulfing foreign bodies and bacteria, independent and complete in themselves. They contain a complex central nucleus, a world within a world, of whose chemistry and physiology we know very little; and outside this lies the surrounding protoplasm, a living jelly, streaming this way and that as the cell moves, and, except for a few scattered granules, almost entirely without visible structure. Plant-cells have firm walls of cellulose, and at the boundary of the animal cell there is a faintly visible film or membrane, which, in a strangely selective and variable way, controls the passage of substances into and out of the cell; and we do not know to what extent there may be partitions of a like nature within the cell itself.



NUCLEUS AND PART OF THE SURROUNDING CELL-SUBSTANCE IN THE GANGLION CELL OF AN OX. (From Bütschli.)

Living matter is really a fluid, passing readily into a sort of jelly. When living it has no visible microscopic structure, and the network or foam-like appearances, often seen after fixing and staining and sectioning, are artificial productions which can be mimicked in gelatine or albumen.

Specialised Cells. In the higher animals the component cells are not of this generalised type, but are nearly all specialised in some particular direction. Some are compacted into orderly pavements and form membranes like the outer layer of the skin and the walls of the blood-vessels. Others form the stringy, elastic connective tissue that binds different organs together. Others are still more elastic and, like powerful springs, ready to contract; these form our muscles. All cells are chemical laboratories, but some are highly specialised in this way and produce quantities of particular chemical substances, such as the

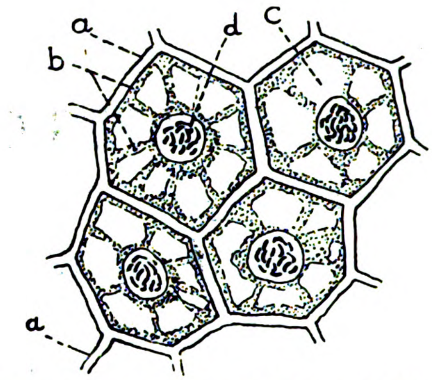


DIAGRAM OF A SECTION THROUGH A FRAGMENT OF PLANT TISSUE, SHOWING FOUR CELLS.

A cell is a unit area or corpuscle of living matter or protoplasm (*b*), under the control of a kernel or nucleus (*d*). In plant-cells in particular there may be vacuoles (*c*) containing very liquid material. The cells here are hexagons, separated by walls of cellulose.

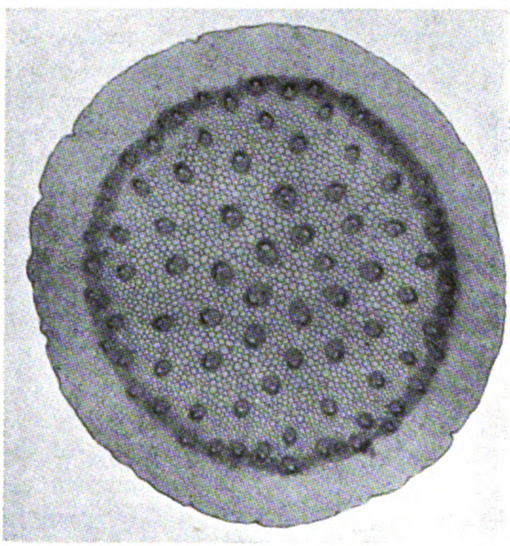


Photo: F. R. Hinkins & Son.

CROSS-SECTION OF THE STEM OF THE BUTCHERS' BROOM.

The stem of a plant contains a number of bundles or strands, which serve partly for strengthening and partly for the transport of sap both up and down. These "fibro-vascular" bundles are seen here as circles imbedded in a ground tissue of large cells.

digestive juices, which they pour either into special ducts or into the blood stream. The chief cells of the blood—the red blood corpuscles—are highly specialised as gas-transporters. Then there are all the various cells of the nervous system, those which receive tidings from the outer world or from other parts of the body, those which send messages down their long thread-like outgrowths, to and from the brain, and the cells of the brain itself, the seat of memory and of thought, activities of the inner or mental life, the physiological side of which eludes our understanding. Walls, girders, springs, gas-carriers, chemical factories, a system of communications! These are but a few of the special purposes to which cells are adapted; and let us note that the generalised cell of the Amœba is, in some measure, each of these things at once. Most marvellous of all are the germ-cells, male and female, simple enough under our closest scrutiny; yet from their union is "minted and coined," in Harvey's phrase, the animal body with all its specialisations and adaptations, true to its race and parentage in every detail. The orderly development of a complex whole from a single cell—that at least is beyond the reach of the generalised cell, Amœba, or phagocyte, or whatever it may be.

Chemistry of the Cell. All cells, whatever their particular tasks, are in some degree chemical laboratories. Let us think of the chemistry of the cell. There are eighty-eight named chemical elements known to exist on the earth's crust,

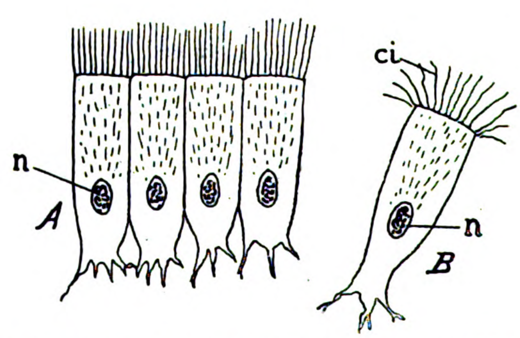
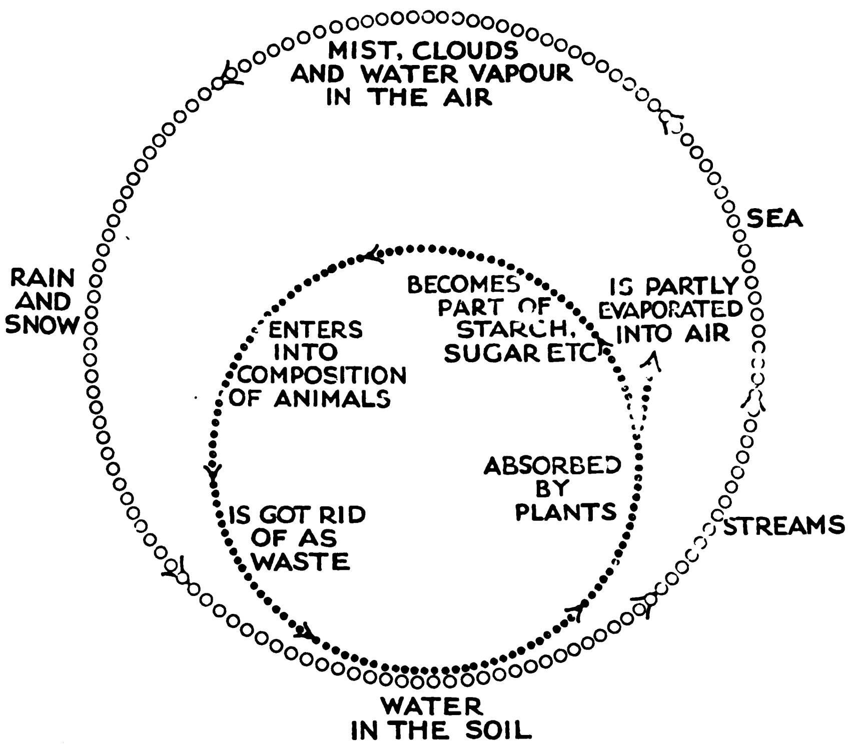


DIAGRAM OF FOUR CELLS OF CILIATED COLUMNAR EPITHELIUM IN A ROW (*A*) AND ONE DETACHED (*B*).

All animals with a body are built up of cells and modification of cells. The cells here figured are from the lining of the windpipe. Each shows living lashes or cilia (*ci*), which straighten and bend at the free end; also a nucleus (*n*) in the middle of the cell-substance.

but, fortunately, only a very few of these have much significance in the life of the animal. The element carbon, which occurs almost pure in the diamond, in graphite, in charcoal or lamp-black, has a special importance, because of its extraordinary power of forming compounds. There are more compounds of carbon known than of all the other chemical elements put together, and they form a special branch of chemistry, which, because of its close connection with living organisms, is called Organic. The reason for this is that each carbon atom may not only unite with, say, an atom of hydrogen on the right and a group of oxygen-plus-hydrogen on the left, it may at the same time be united with other similar carbon atoms before and behind. This power of forming chains of similar atoms, with all manner of other elements attached on either side, is almost peculiar to carbon, and is of the very greatest importance. The sugars are chains of carbon atoms, six or twelve in number, united to oxygen and hydrogen, and most of the fats are triple chains of which each branch contains about twenty carbon atoms; the starches are whole series of sugar-groups united together; and in the proteins, in some ways the most essential and characteristic constituents of living matter, atoms of carbon and nitrogen alternate to form a vast structure which chemistry has never yet completely unravelled or imitated. Sugars and starches, fats, proteins: these are the three great classes of compounds which go to form living matter; and the chain-forming power of carbon is essential to each of them.

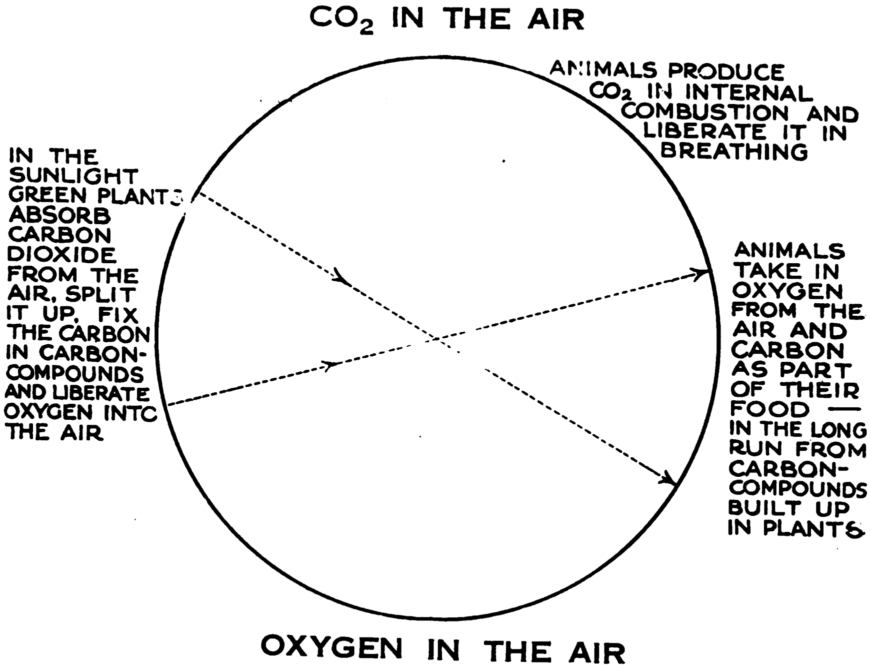


CHEMICAL AND PHYSICAL CYCLE OF WATER.

In the outer circle water passes from the soil to streams, and thence to the sea. It rises as mist from the sea and forms clouds. Thence it is precipitated as rain and snow, and is water once more in the soil. In the inner circle the water in the soil is absorbed by plants, is partly lost as vapour, but is partly used in building up carbon-compounds. These are eaten by animals, and the surplus water returns to earth.

The three other elements mentioned above, nitrogen, oxygen, and hydrogen, are all gases, and the air we breathe is a mixture of the first two. But nitrogen does not readily combine with other elements, and though it enters the lungs it is not really taken into the body (*i.e.*, the living cells) in breathing, as oxygen is; the nitrogen which the body requires for its proteins is all obtained from the food, and it behaves in the body in quite a different way from the other elements. Sugars, fats and proteins all contain some oxygen and more hydrogen. Little notice need be taken of the other elements essential to life: many of the proteins contain sulphur and phosphorus; the saltness of blood or tears is due, like the saltness of the sea, to dissolved minerals such as sodium chloride; bone is a compound of phosphorus with calcium, the element present in lime; and small traces of many elements, especially of iron, are essential to the life of the cell.

Carbon, hydrogen, oxygen, nitrogen—these are the most important of the elements with which the laboratory of the living cell deals. The next question is, how does it deal with them? A complete answer to this is the goal of

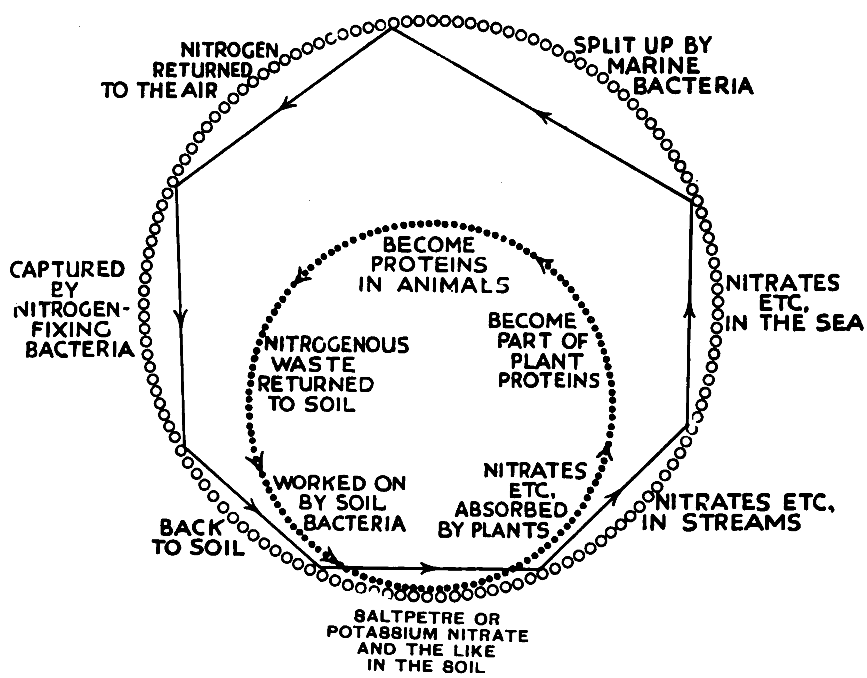


PART OF THE CHEMICAL CYCLE OR CHAIN OF CARBON AND OXYGEN.

Carbonic acid gas passes from air to plant; carbon-compounds pass from plant to animal; carbonic acid passes from animal to air. Oxygen passes from plant to air, from air to animal.

in the least chemically similar to life, as we know it, could exist in the absence of water. Its chemical and physical properties, such as its great power of dissolving other substances, its resistance to changes of temperature, its resistance to the passage of electricity, and its great power of forming colloidal or jelly-like systems with the complex carbon-compounds of living matter, all these are of fundamental importance not only to such animals and plants as live in the the science of bio-chemistry, the chemistry of life, a goal not yet attained in spite of a great and rapid progress of knowledge, of which only the broadest outline can be sketched here.

One of the great foundation-stones of the chemistry of life has already been mentioned—the formation of long chains of carbon atoms. Another, of even deeper and wider significance, is *water*. It is easily possible to imagine some other element replacing carbon, without too much change in chemical processes resulting; but nothing



CHEMICAL CHAIN OR CYCLE OF NITROGEN.

Nitrates and the like in the soil are dissolved out by streams and pass to the sea. Thence, through the agency of de-nitrefying bacteria, nitrogen is returned to the air. By means of nitrogen-fixing bacteria, such as those in the roots of leguminous plants, the nitrogen of the air can be recaptured and brought back to the starting-point in the soil.

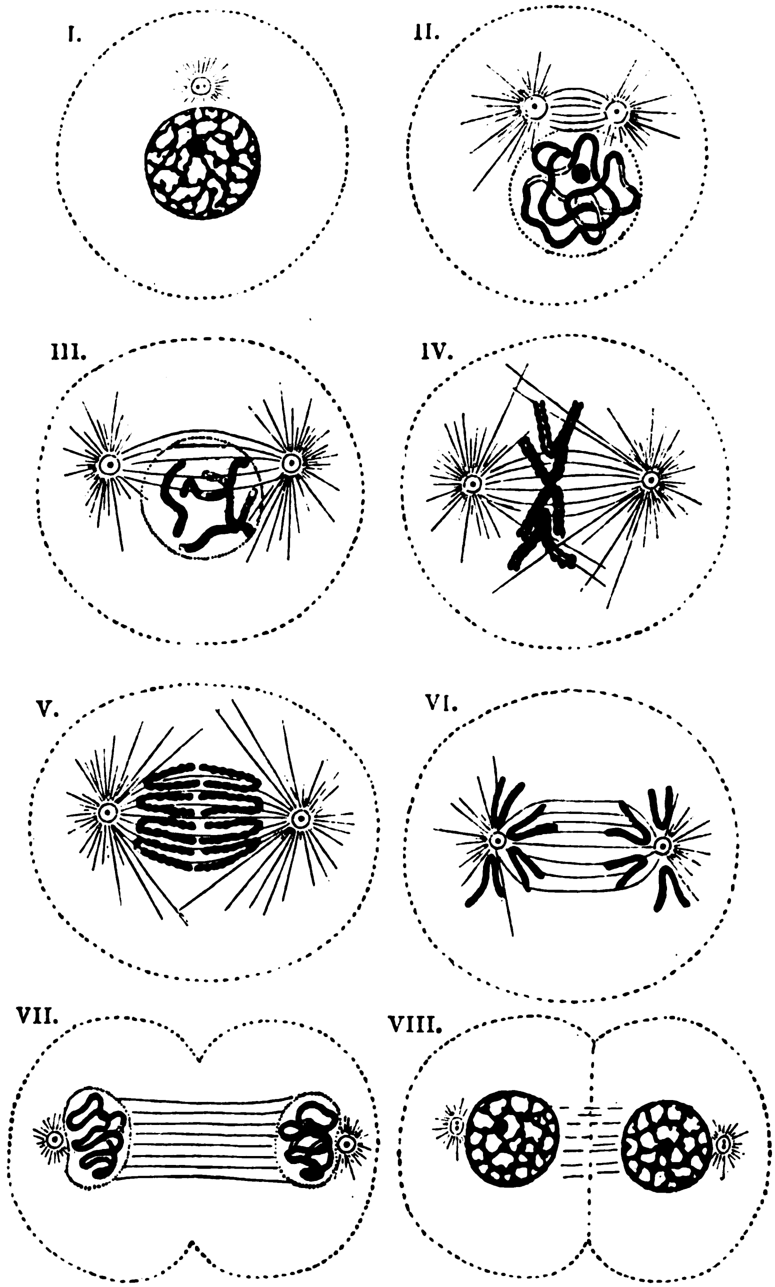
The inner circle shows how nitrogen from the soil's nitrates becomes part of plant proteins and thence of animal proteins. The decaying bodies of plants and animals and the waste-products of animals bring back the nitrogen to the soil, again with the help of bacteria.

seas or the rivers, but to all living things. For a great part of the weight of the animal body is the weight of the water it contains, which bathes the whole, passing from cell to cell, and remains the medium in which the chemical processes of life are carried on, even in animals and plants of the "dry" land and the air. The body can resist lack of solid food and great loss of weight much better than it can stand being deprived of water. In an even deeper way, as we shall see, the properties of water may serve to illustrate and explain the great types of chemical processes that are carried on by the laboratory of the living cell.

Up-building and Down-breaking.

The first of these is the process of analysis and synthesis, the breaking-down and building-up of long carbon chains, link by link. The green plant, starting with compounds so simple as water and carbon dioxide, builds up complex sugars and starches; and though animals cannot quite achieve this, they, too, have a great power of joining links together and forming chemical chains. Indeed, this is one of the most important properties of living matter: *the power to construct.* When cane-sugar, whose molecule is a chain of twelve carbon atoms, is digested, it is split into two shorter chains of six atoms each, and passes into the body in this simpler form; these short chains may be joined together again, within the body, to form a complex substance, called glycogen or animal-starch. The proteins of the food undergo an even more extensive breaking-down and reconstruction.

One point must be emphasised: it is easy to pull two links apart, but difficult to join two



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THE ORDINARY PROCESS OF CELL-DIVISION (MITOTIC DIVISION WITH KARYOKINESIS).

The most important fact is that when a cell divides into two after the fashion called mitotic or karyokinetic, each of the daughter-cells has a very precise half of everything that there was in the original cell. 1. The nucleus in a resting state; one centrosome in the cell-substance outside the nucleus. 2. The centrosome divides into two; the nuclear rods or chromosomes can be counted; here there are four. 3 and 4. The chromosomes become arranged at the equator. Each is split longitudinally into two. 5 and 6. The halves of the chromosomes, somewhat horse-shoe-like, move along the delicate spindle towards each of the centrosomes. 7 and 8. Two new nuclei are constituted; one cell becomes two cells; the resting state is resumed.

links together. Construction requires energy, which the plant cell obtains from the sunlight and the animal cell from its chemical stores; it is construction, or synthesis, which is characteristic of living matter.

The Living Fire

The second great chemical process that goes on in the living cell or the living body is the burning of the fire of life. The first great step in the science of the chemistry of life was the comparison of the animal body to a flame. To understand the complex life of the one, we must study the other.

Candle grease consists mainly of compounds with long carbon chains, to which are attached atoms of hydrogen. When the melted grease burns in the wick, the chains break up and the carbon atoms and the hydrogen atoms combine, as far as they can, with atoms of oxygen from the air. That is why a candle—or a fire—goes out if it cannot get enough air. When there is an ample supply of oxygen, however, the carbon atoms combine with it to form carbon dioxide:

$$O = C = O$$

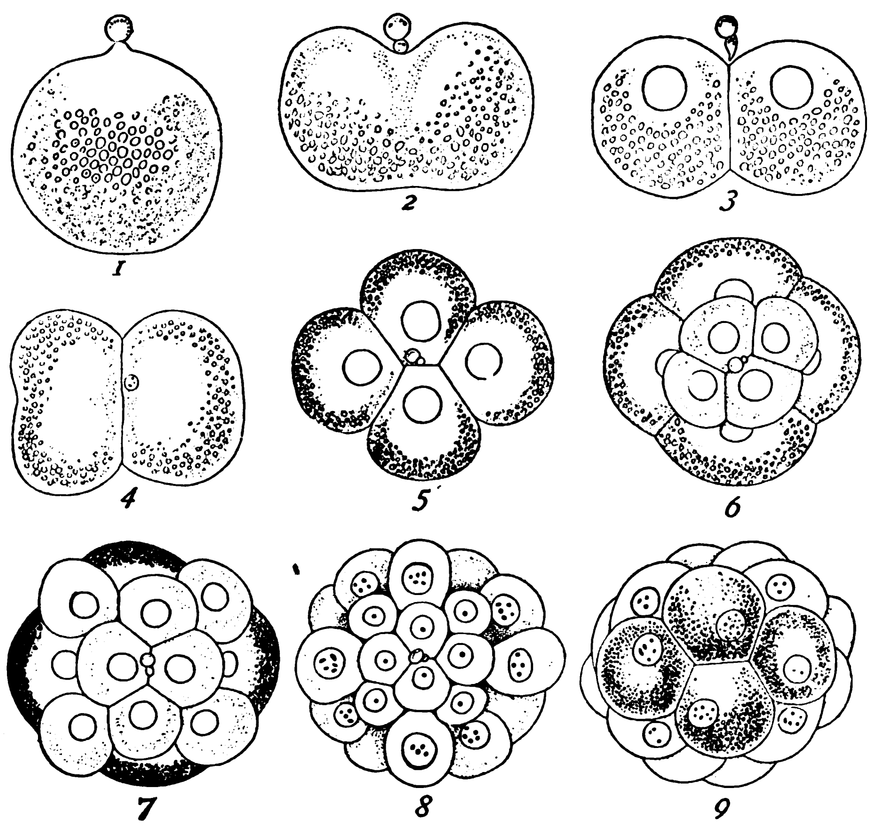
and the hydrogen atoms combine with it to form water:

$$H - O - H.$$

When all the carbon atoms and all the hydrogen atoms have taken up as much oxygen as they possibly can, that is to say when they form carbon dioxide and water, the burning process is over.

In the living cell exactly the same process takes place, though, of course, more slowly. The long carbon chains of fats, sugars and proteins are split up, and their carbon and hydrogen atoms combine with oxygen to form carbon dioxide and water. The energy which the candle gives off as light and heat is used by the living cell for various purposes: it keeps up the heat of the body, furnishes energy for the contraction of muscles, enables other compounds to be constructed, and also furnishes electrical energy. Living matter is always smouldering, or, as the chemist says, always partly oxidised; sugars, fats, and proteins are combined with oxygen, and the process yields carbon dioxide, water, and *energy*; that is the gist of the whole thing, and the whole of the chemistry of life is based upon this one fact of burning, combustion, respiration, oxidation, or whatever we care to call it.

We may regard water as a neutral point in the process of burning or oxidation,



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SEGMENTATION OF THE EGG OF THE POND-SNAIL PLANORBIS. (After Rabl.)
(Magnified about 300 times.)

1. The ripe egg gives off the first polar body, which carries off half of the chromosomes of the nucleus (reducing division). 2 and 3. It gives off a second polar body, but there is no further reduction in the number of chromosomes, for each is split longitudinally. 4. The egg-cell or ovum divides into two cells or blastomeres. 5. Cleavage or segmentation into four cells. 6 to 9. A ball of cells is formed, some larger, some smaller

with its two atoms of hydrogen and one of oxygen :

Rôle of Water.

H — O — H.

Any compound which contains more hydrogen than this can take up more oxygen, till water is formed again ; it is still capable of being "burnt." A compound which contains more oxygen, such as hydrogen peroxide (H_2O_2), readily gives up the excess and returns to the neutral point — water ; the chemist uses this compound for bleaching and the living cell applies it to many problems. This is an important idea to think over—the idea of a balance between oxygen and hydrogen, whose neutral point is water.

Water (H_2O) is a neutral point in another sense. It may be thought of as divided in another way: (H —) (— O — H). On the hydrogen side it leads towards the corrosive acids, and on the oxygen-plus-hydrogen side to the caustic alkalies, both of which are powerful chemical tools. Even a slight disturbance of this balance may have disastrous consequences for the living cell, and the neutral point is somewhat strictly adhered to.

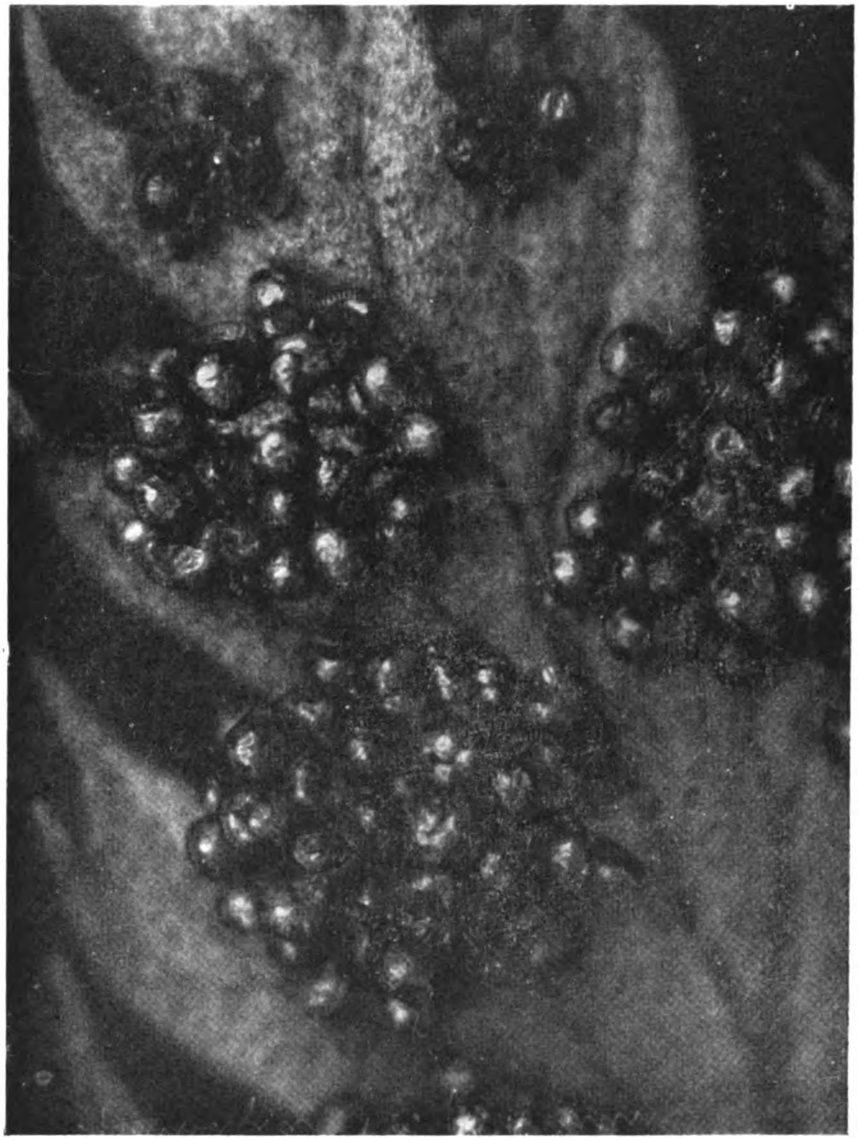


Photo: John J. Ward, F.E.S.

A PHOTOGRAPH (HIGHLY MAGNIFIED) OF RIPE POLLEN-GRAINS FALLING FROM THE STAMENS OF A MALLOW FLOWER—AN ENORMOUS QUANTITY OF LIVING MATTER.

Each grain is a germ-cell, in the strict sense a spore-cell. Its nucleus divides into a pollen-tube nucleus and a generative nucleus. The latter forms two male-cells, and one of these fertilises the egg-cell, within the ovule, within the ovary. The egg-cell then divides and re-divides to form the embryo.

The chemist's chief tools, then, are acids, alkalies, and heat. Living matter is delicate,

Ferments.

and cannot make very full use of these two-edged weapons. The chief tools of the laboratory of the cell are called "ferments" or "enzymes." They occur in all cells; their chemical structure is unknown, but certainly complex ; and their function is to promote, assist, and control the reactions which go on within the cell. The power of forming these ferments is characteristic of living matter, and of the greatest importance.

The chemical activities of the cell may now be summarised in a few words. The living protoplasm is a thin watery jelly of proteins, fats, and sugars. Oxygen is constantly entering

the cell, and combining with the carbon and hydrogen atoms to form water and carbon dioxide. This process yields energy, which is used to supply heat, or energy of movement, or electrical energy, or the energy required to build up complex substances. In this building up, and in the burning, the complex ferments made by the cell exert a controlling influence. The consumption of oxygen, the formation of complex substances, and the use of ferments: these are the three great characteristics of the chemistry of the living cell.

§ 2

THE CHEMISTRY OF THE FOOD

SINCE its cells have so great a power of building up their own complex constituents from simple materials, the animal does not require to find these constituents ready-made in its food. It has not, of course, as much independence as the green plant, which erects the most complex chemical edifices with the simplest of materials—carbon dioxide and water. But an animal can live and thrive, for example, on a diet containing no proteins but only the simpler amino-acids, of which each protein molecule is a vast aggregate. Indeed, there are so many kinds of amino-acids, and so many in each protein, that every kind of animal has its own unique and peculiar proteins; and the introduction of a "foreign" protein into the blood may have most serious effects.

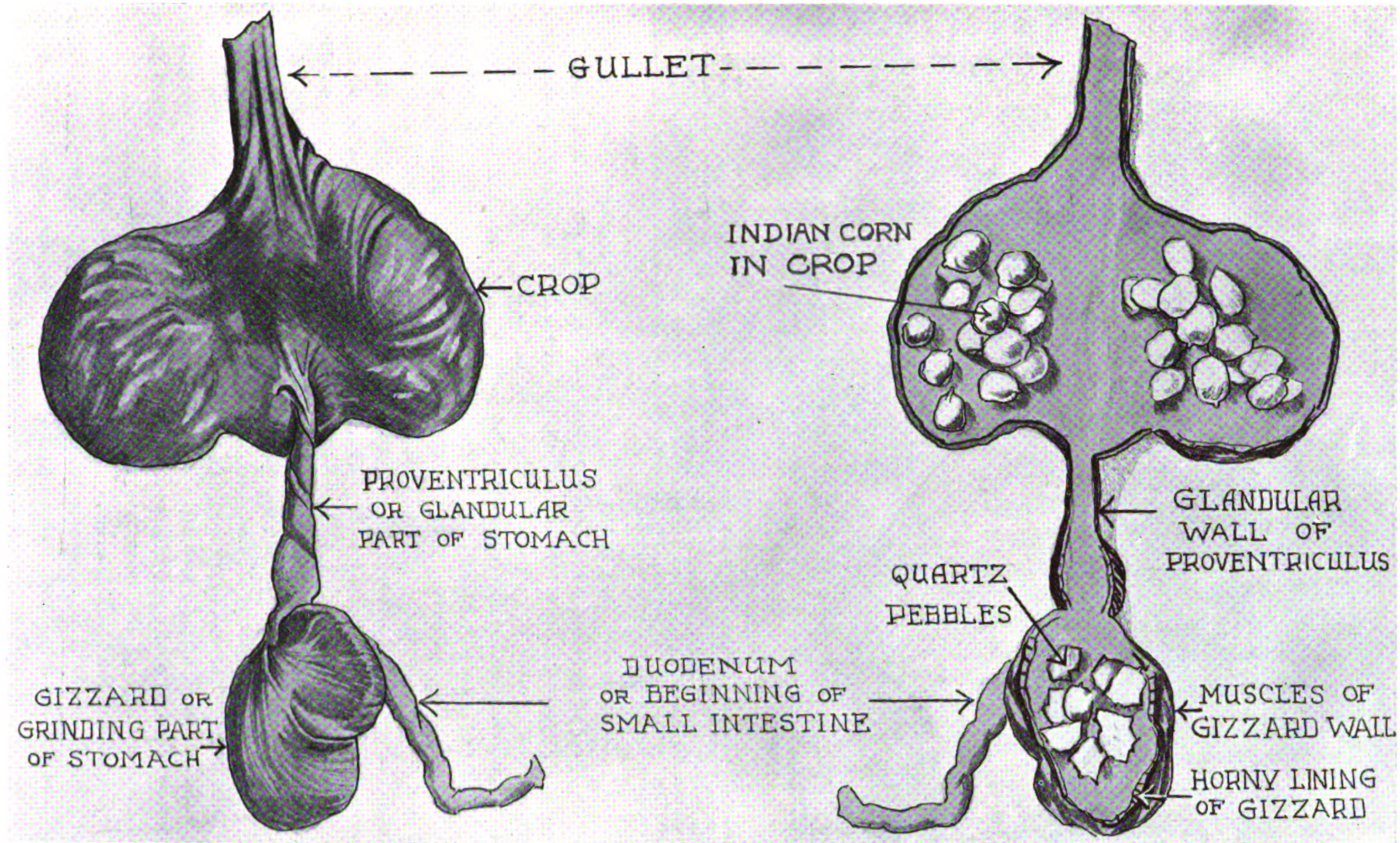
Digestion.

But amino-acids, however desirable they may be as a food, do not occur very commonly in nature, whereas proteins bulk largely in the diets of all animals, whether eaters of flesh or eaters of grass. What happens is that the protein of the food is attacked, simplified, and split-up into amino-acids, which are absorbed by the body and reconstructed, in a new way, into the proteins characteristic of the animal in question. One building is taken to pieces, the stones moved one by one, and built again into a new building in a pre-determined style of architecture. The process of taking the food to pieces is called *digestion*. It is carried out by means of ferments or enzymes, not unlike those which within the cell control the processes of oxidation and synthesis, but with one great difference: the work is done, not inside cells, but in a space surrounded by cells, the alimentary canal—stomach and intestine. Many of the cells which line the alimentary canal pour into it enzymes and other chemical substances which aid the process of digestion.

The simplifying or digestive process may then be regarded in a slightly different way: it answers the question of how the foodstuffs are to be got from the alimentary canal into the surrounding cells, and thence into the blood, to be transported to various parts of the body. Protein molecules are too large to be absorbed and transported in this way; they must first be broken down by digestion into amino-acids. So that even a purely cannibalistic animal, feeding on proteins identical with those of its own body, must needs break them down and build them up again. This way of looking at digestion, as a simplification necessary before absorption and transport can take place, is particularly important in connection with the fats. These are split into parts (glycerine and fatty acids) by digestion, absorbed in parts, and immediately put together again. The subsequent transporting of the fats is carried out in a rather special way.

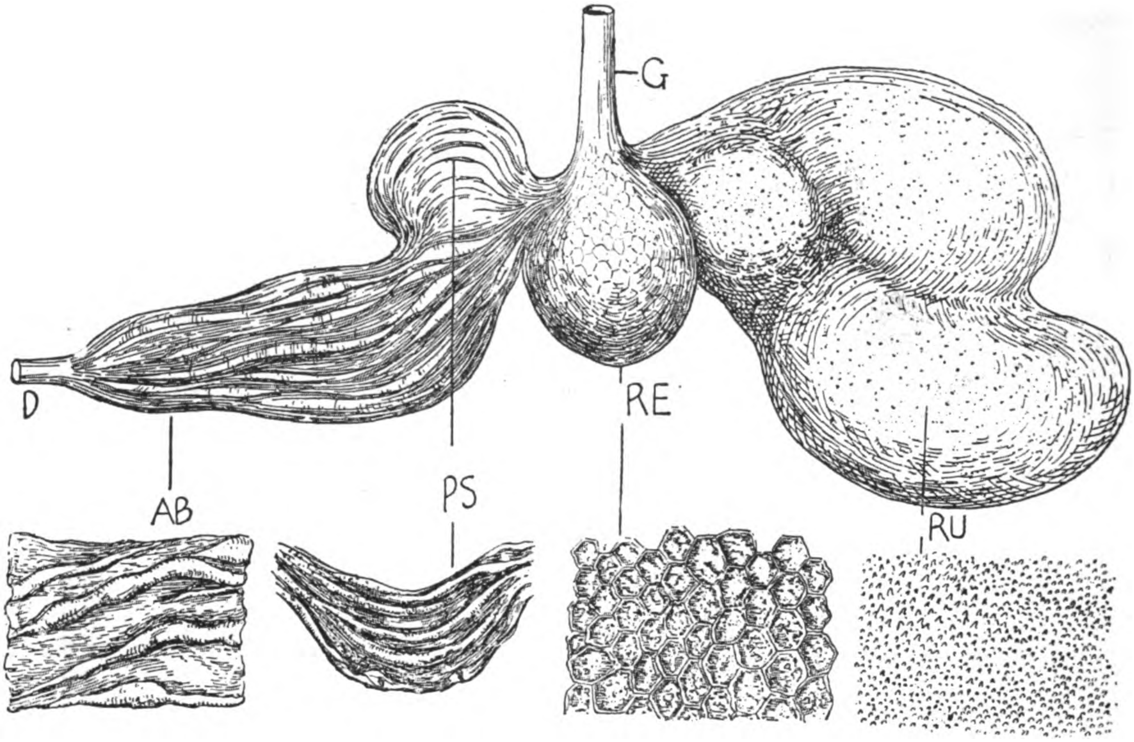
The first part of digestion is mechanical grinding. This does not by any means stop short with the teeth: there is a continual churning up of the undigested food during the first part of its passage down the alimentary canal, a process which also serves to bring it properly into contact with the digestive juices. Many animals have special provision for grinding up the food: thus birds swallow rough pebbles, which remain, till their corners are rounded off, in the muscular gizzard and act as grindstones. The "gizzard" of the lobster is a complicated mill.

The chemical processes of digestion proceed in an orderly manner and step by step. They begin with the saliva of the mouth, which contains an



CROP AND GIZZARD OF A PIGEON.

The crop is an enlargement of the gullet and serves as a storehouse for the hastily swallowed food. Pigeon's milk is due to a degeneration and shedding of the cells lining the crop. The stomach includes two very different portions—the soft-walled glandular proventriculus and the hard-walled grinding gizzard which has a horny lining and encloses little pebbles. As the pebbles become smooth in the grinding, they slip down the intestine, and others must be swallowed if the bird is to keep in health.



STRUCTURE OF THE SHEEP'S STOMACH.

The hastily chewed grass passes down the gullet (G) into the first chamber (RU), the rumen or paunch, whose internal surface, shown below, is like velvet pile. An overflow of sappy fluid passes into the second chamber (RE), the reticulum or honeycomb, whose hexagonally-marked internal surface is shown below. Boluses of grass pass from the paunch up the gullet to the mouth and are thoroughly chewed (" chewing the cud "). Passing down the gullet again, the chewed grass skips the first two chambers and passes along a groove into the third chamber (PS), the psalterium or manyplies, which has many internal plaits, shown below. Thence the food passes into the true stomach (AB), the abomasum or reed. D is the duodenum, the beginning of the small intestine.

enzyme capable of splitting starch into sugar. The first step in the splitting of proteins is taken by the "pepsin" juice of the stomach; and into the stomach, too, is poured considerable quantities of acid. Further on, in the "duodenum" of backboned animals, the pancreas pours in a powerful juice which contains protein-splitting, fat-splitting and starch-splitting enzymes, whose action is greatly aided by the "bile" juice contributed by the liver. Unable to carry on the digestion of itself, bile is, nevertheless, a valuable ally. At the same time the reaction changes from acid to strongly alkaline. Strong acids and alkalies, which cannot be allowed to accumulate in the cell itself, may do no harm in the cell-surrounded channel of the alimentary canal, and the same is true of the powerful ferments. In the long coils of the small intestine, the proteins are finally resolved into amino-acids, the sugars and starches into simple forms with only six carbon atoms, and the fats are also divided. It is here, too, that the lining cells of the enormous surface of the tube, a surface increased by finger-like projections, absorb from the digested food the simple compounds which they pass on to the blood.

Steps in Digestion.

The lower levels of the alimentary canal are crowded with bacteria, simple one-celled plants, which thrive exceedingly upon the undigested food. They, too, form powerful enzymes, and may help in the process of digestion in this way, and may also be useful in destroying poisons. Moreover, they attack substances which resist the animal's digestive juices. But they tend to produce gases, and evil-smelling compounds, and even poisons with which the body has to cope. If the bacteria increase beyond normal limits, they may constitute a serious menace: but, though uninvited guests, they are not too easily turned away.

The food, then, must consist of substances out of which the animal can build the sugars, fats, and proteins it requires; and usually will consist of other sugars, other fats, and other proteins, which are taken to bits step by step in the

process of digestion, absorbed in fragments, and rebuilt in a new and appropriate way. The digestion is carried out by ferments made by the cells which line the alimentary canal; some of the ferments are aided by the presence of acids, and others by alkalies, while all are favourably influenced by the relatively high and constant body-temperature of the warm-blooded animals—mammals and birds.

Since all proteins do not contain the same amino-acids, it follows that some are more valuable as foods than others. There are some of the amino-acids that are essential to the continued life of the cell, and others are required if growth is to take place. Some proteins, chiefly derived from plants, are deficient in these most valuable constituents, and hence unable to support life of themselves. The distinction between "good" and "bad" protein is fundamental in all problems of nutrition.

Kinds of Food.

There are, moreover, to be considered those chemical elements which the animal body requires in greater or less amounts, although they do not seem to be necessarily bound up with the most central and distinctive processes of the chemistry of life. In the more highly evolved animals, at any rate, there are many substances which must be present in the diet; fortunately, it is not often necessary to take special precautions to supply them. Thus, most flesh-eating animals get as much as they require of the ordinary mineral salts, such as sodium and potassium chlorides, without knowing it; but some eaters of grass are periodically driven to the seashore or to outcrops of natural rock-salt to make good their deficiencies in this respect. Iron has to be supplied to sufferers from anæmia; the occurrence of goitre in certain regions is probably due to the absence of iodine; and this list could probably be greatly multiplied if we knew more of the function of some of the elements present in the body.

Two elements on which much attention has been focussed in recent years, and which seem to be closely inter-connected, are calcium and phosphorus, whose compound calcium phosphate is the chief hard constituent of bone. Obviously both must be supplied, and, it would seem, supplied in the right proportion, when bones are being formed or repaired. Calcium is essential, too, to the life-saving process of clotting which occurs when a wound allows the blood to escape either outwardly or within the body. Phosphorus plays an even greater part in the life of the body, and partly because it combines to form compounds which are not very stable and easily disintegrated. Phosphoric acid combines with the sugars, and it seems likely that all the sugar burnt in the body, and all the phosphorus which goes to form bone, passes through the stage of being sugar-phosphate. The nucleus of the cell contains very complex proteins, which contain sugar, and phosphorus, and complex groups allied to uric acid. The fats, too, form compounds with phosphorus, and, perhaps, when fat is transported about the body some of it is changed into this form for convenience. These phosphorus-fats, too, occur in every cell and are, no doubt, of the greatest importance, perhaps because of their very great readiness to change or break up; and especially, and, perhaps, significantly, are they associated with the cells of whose working we understand least—the nerve cells. Phosphorus and calcium, then, are two elements quite essential to the life of the body; and in some way not very clear, they are connected together.

Calcium and Phosphorus.

But apart from the obviously essential things, like sugars, fats, proteins, and water, and the equally intelligible salts and metals and phosphorus and so on, there are still certain substances which must be present in a diet which allows to the animal the full measure of life. The first hint of the existence of these necessary substances was faintly heard very long ago, in the days when sailors, especially in whaling voyages, fed chiefly on preserved food and suffered severely from scurvy; a disease which they escaped if fresh meat and fruit were available. It turned out, too, that if rats were fed on a diet of carefully purified fat, sugar, protein, and so on, as much as they could require, yet free from all traces of impurities, they did not thrive; they lost weight and eventually died. But if a very small amount of fresh, unpurified milk were added to this "artificial" diet, the rats throve. It was clear that there were substances hitherto unknown, which the animal body required and could by no means do without, but of which it required only very small amounts.

Vitamins.

These unknown substances were named "accessory food factors" or "vitamins"; and, to the chemist, unknown they remain to this day. There are two, we know, present in most natural fats—cod liver oil, butter, beef-fat, and so on. In the absence of one of these, animals cease to grow and suffer from disorders of the eye; in the absence of the other, their bones are not properly formed and they suffer from "rickets." It seems, however, that light—ordinary sunlight in the one case, the ultra-violet light of the quartz-mercury lamp in the other—is a great preventive of these results of "vitamin deficiency." Two other vitamins are not associated with fats, but occur in milk, yeast, fruit, and so on; the results of deficiency of these factors are the diseases beri-beri and scurvy.

That there are certain substances, of unknown composition, in whose absence the animal does not thrive, is certain. But the whole question, with the distinction between "good" and "bad" protein, and the necessity for who knows how many chemical elements, is not yet unravelled. Meanwhile, let us remember that a normal and natural diet, with fresh foods, with not too much cooking and stirring, with not too much husking and paring, will supply all the "good" protein, and chemical specimens, and vitamins, that anyone can require. It is pleasantest to be disciples of Monsieur Jourdain, and eat chemicals all our lives without knowing it.

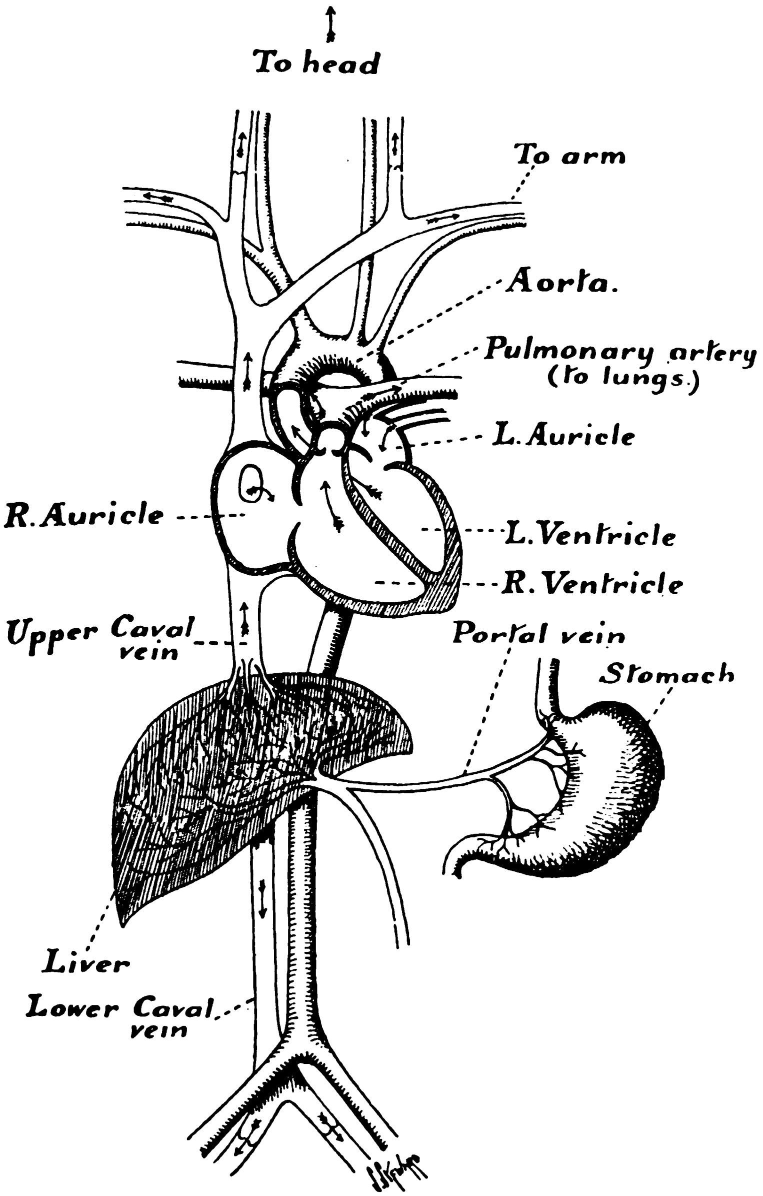
§ 3

THE CIRCULATION OF THE BLOOD

WE see and feel the throbbing of the pulse on our wrist; we know that an artery is expanding because the left driving chamber or ventricle of our heart is contracting. There should be about seventy or eighty contractions in a minute, and three or four ounces of blood are forced out at each beat. The continued beating is automatic in the sense that it is part of the nature of the heart muscle to beat, but it is influenced by the nervous system, which supplies both spur and curb. The heart, which is about the size of our closed fist, has two receiving chambers or auricles, the right for impure or venous blood from the body, and the left for pure blood from the lungs. It has two driving chambers or ventricles, the right for driving impure blood to the lungs, and the left for driving pure blood to the body generally. In the great arterial trunk or aorta which bends over to the left side the rate of flow is about sixty feet per minute, and may be compared to the stream of water from an ordinary household tap. The rate lessens as the blood is forced from the main streams into the tributaries: when an artery is cut the blood comes out rapidly in spurts, corresponding to heart beats; but when we cut some minute superficial capillaries, as we often do, the blood oozes out slowly and steadily.

As to the circulation, the pure blood urged outwards from the heart flows through the arteries, and thence into very fine capillaries which form networks in and around the tissues. There is a passage of dissolved substances and oxygen from the capillaries into the fluid, called lymph, that bathes the tissues; and thus they are nourished and toned up and supplied with the oxygen necessary to keep the fire of life burning. But the network of capillaries begins to give rise to larger tributaries, which become veinlets and then veins, and now the blood is on its way back to the heart. The veins are not so thick nor so elastic as the arteries, and they are abundantly supplied with valves, which allow the blood to flow only heartwards. Thanks to these, every movement of our limbs helps to urge the blood in the veins—where it no longer feels the force of the heart-beat—in the right direction, and that is why it is so much more tiring to stand still than to walk. If we stroke our arm towards the hand we see in the bluish veins little temporary swellings; we are making temporary dams where the valves are. If we tie our arm tightly with string, the part below the string will soon become pale and cold; we have cut off the arterial supply of blood. We have almost proved the circulation!

To return to the veins carrying the impure blood from the body, they lead eventually into the right auricle of the heart, and thence the blood passes through a valved portal into the right driving chamber or ventricle. When the right ventricle contracts, at the same time as the left, the impure blood is driven direct to the lungs, and spread out in numberless capillaries on their enormous internal surface. The blood loses its surplus carbon-dioxide and gains fresh oxygen from the in-breathed air which fills the lung; and then again the capillaries run together to form eventually the large pulmonary vein, which leads to the left auricle of the heart. Just as the pulmonary artery is the only artery which carries impure blood, so the pulmonary vein is the only vein which carries pure blood. From the left auricle the pure blood passes through the valved portal into the left ventricle which drives it through the great arterial trunk to the head and body. There is a short *heart-lungs-heart* circuit and a long *heart-body-heart* circuit; but it is one continuous system, and indeed the two circuits are the two loops of a figure-of-eight, with the heart at the centre. On an average, they say, it takes an imaginary drop of blood about forty-five seconds to make a circuit, and if we could suppose a drop of blood to retain its individuality, it might be said to make a journey of a mile in a day. If all the capillaries of our body were placed end to end they would reach across the Atlantic! It should be added that the circulatory system just described does not quite complete the whole: the tissue-bathing fluid (lymph) diffuses in part into the capillaries, but also is collected into lymphatic vessels within which there is a valve-regulated flow; at intervals there are minute filters or nodes



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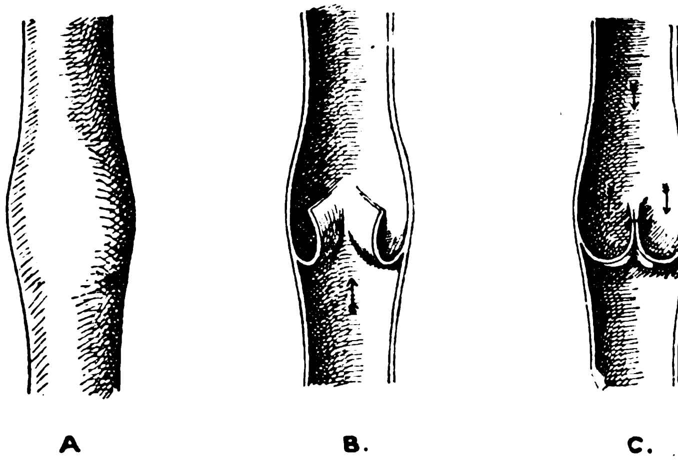
THE GENERAL SYSTEM OF VEINS AND ARTERIES.

Into the right auricle comes all the impure blood from the body by the anterior and posterior caval veins. It passes into the right ventricle and is carried to the lungs by the pulmonary arteries—the only arteries carrying impure blood. From the lungs the purified blood returns by the pulmonary veins (the only veins carrying pure blood) to the left auricle, and thence to the left ventricle, whence it is carried to the head and arms and posteriorly by the dorsal aorta, which splits far back into two iliac arteries for the two hind limbs. The portal system of blood-vessels gathers digested proteins and carbohydrates from the stomach and intestine, and the portal vein breaks up in the liver. The altered blood is eventually collected from the liver by tributaries of the hepatic veins, and these lead into the upper caval vein, or, what some would call, the upper part of the inferior vena cava.



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VALVES OF THE VEINS.

A, a swelling on a vein, indicating the presence of a valve within it. B, the vein laid open, showing the valves partly open: blood flowing in the direction of the arrow will have free passage between the valves. C, showing the valves shut: blood forced backwards in the direction of the arrows will find the valves closed against it.

which strain out injurious substances from the clear fluid.

This is obviously a very bald account of remarkably well-adjusted arrangements; it leaves out the adaptations which secure a steady flow without either too much or too little blood, which prevent the current reversing, which offer alternative routes should one be blocked, and so on. It leaves out also the story of the many nerve-fibres which run to the arteries, causing them to become firm and small, or loose and expanded—automatic, watchful nerves beyond our control, as those who suffer from sudden pallor or flushing know only too well. There are, also, the two great nerves of the heart, one of which causes it to accelerate, the other to slow down, and they again are to be stimulated only by internal messages from the body, and not by our will.

History of Discovery.

So far, what every person, so to speak, knows about the circulation—all very easy as long as we keep to superficial aspects. And yet, as regards this surface knowledge, which is everyone's property to-day, how long is the story of attainment, told so well in Dr. Singer's "Discovery of the Circulation of the Blood." The Egyptian physicians felt the pulse in 1500 B.C., and Hippocrates connected it with the heart. Yet the Aristotelian school made the heart the seat of intelligence and the source of bodily heat. In the second century of the Christian era Galen, a student of the medical school of Alexandria, who became physician to Marcus Aurelius, formulated views which remained current for fifteen centuries, influencing our poetical literature, for instance, down to the time of Shakespeare. The older poets could not get on without dragging in the heart! But Galen's views, though including the radically sound idea of "vital spirits" being distributed from the heart, through the arteries to the body, were full of impossibilities. Against some of these the awakening spirit of independent observation began to rebel in the sixteenth century, headed by the inquiries of that towering artistic and scientific genius, Leonardo da Vinci, who showed, for instance, the practical significance of the valves at the roots of the great arteries and the erroneousness of Galen's view that the pulmonary vein took *air* to the heart.

Then came the somewhat comic chapter of which Vesalius, a Belgian professor at Padua, was the hero. He worked out a splendid "Fabric of the Human Body" (published in 1543), which was based on personal observations and was a scientific landmark. Vesalius saw for himself that Galen was quite wrong in supposing that blood passed through pores from one ventricle of the heart to the other, and yet he seems to have refrained from saying so until he had resigned his professorship and become physician to the Emperor Charles V, the greatest monarch of his age. Then came a new outspokenness. Even the great anatomists are not untouched by human weakness.

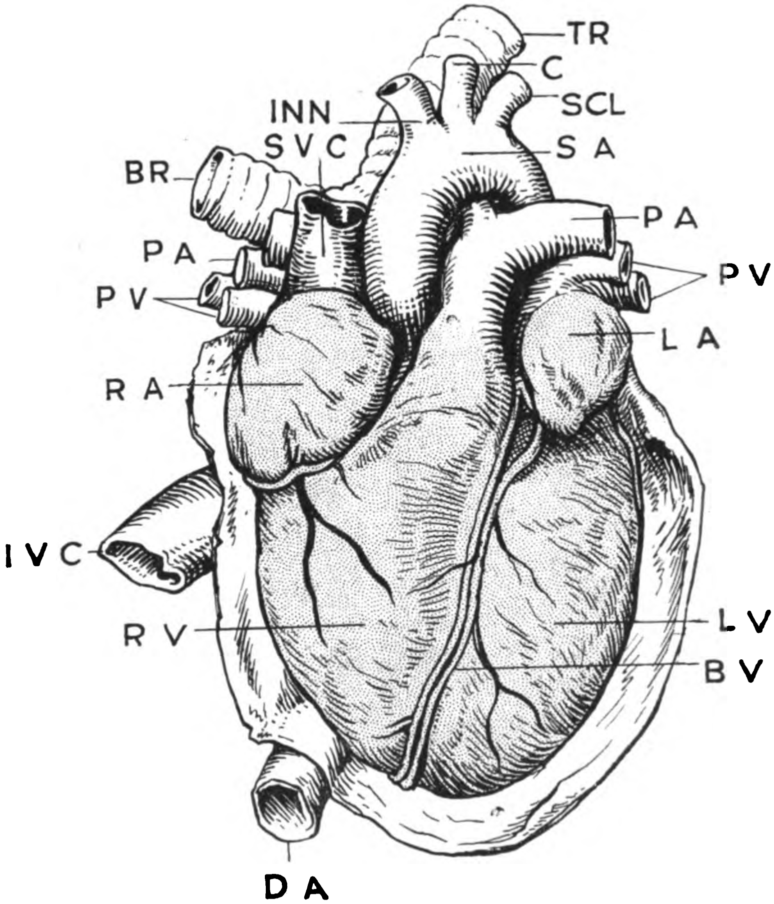
The next chapter is a tragic one, for it concerns Servetus (1511-1553), physician and theologian, who gave the first clear account of the *heart-lungs-heart* circulation, yet hardly knew what he had done. "So near, and yet so far from, being a great physiologist." For his heretical "Restitution of Christianity" the Protestants burned him alive in Geneva, and the Catholics just a little behind time, had to be content with burning his effigy.

The credit for making the circulation clear

rests, as everyone knows, with Harvey, though it would be absurd to deny that he was influenced by his predecessors, especially by Fabricius, his anatomical teacher at Padua. In Harvey's "Anatomical Dissertation concerning the motion of the Heart and Blood in Animals," published in 1628 and dedicated to King Charles I (who is likened to the heart !), it is shown by arguments based on dissection and experiment, " that the blood in animals is impelled in a circle, and is in a state of ceaseless movement ; that this is the act or function of the heart, which it performs by means of its pulse . . . . I saw that the blood, forced by the action of the left ventricle into the arteries, was distributed to the body at large and its several parts. In the same manner it is sent through the lungs, impelled by the right ventricle into the arterial vein (pulmonary artery)." So was enunciated the great discovery which changed the whole science of physiology and the whole practice of medicine. It was reserved for Malpighi in 1661 to observe what Harvey had only inferred—the capillary network connecting the ends of the arteries with the beginnings of the veins ; for Swammerdam to see the red blood corpuscles ; for Leeuwenhoek in 1688 to give in the web of the frog's foot ocular demonstration of the circulation of the blood, which he had himself forcefully disbelieved—and there are other links in the chain. But the fundamental clear thinking was Harvey's, and he had the unusual satisfaction of having his conclusions generally accepted within his own lifetime.

Before passing on to consider what exactly the blood does for the body, and the meaning of this complex system of communications—so vital that the beating of the heart is considered the surest sign of life—it may be well to describe simply the nature of the blood itself, the fluid distributed so carefully to all parts of the body. The most important fact is that it is not a simple, homogeneous fluid. There is, of course, a fluid "background," the blood *plasma*, pale and watery, containing dissolved gases, food materials and mineral salts. The last give the blood its salt taste, and it is interesting to note that they are present almost in the same proportions as in

Blood Corpuscles.



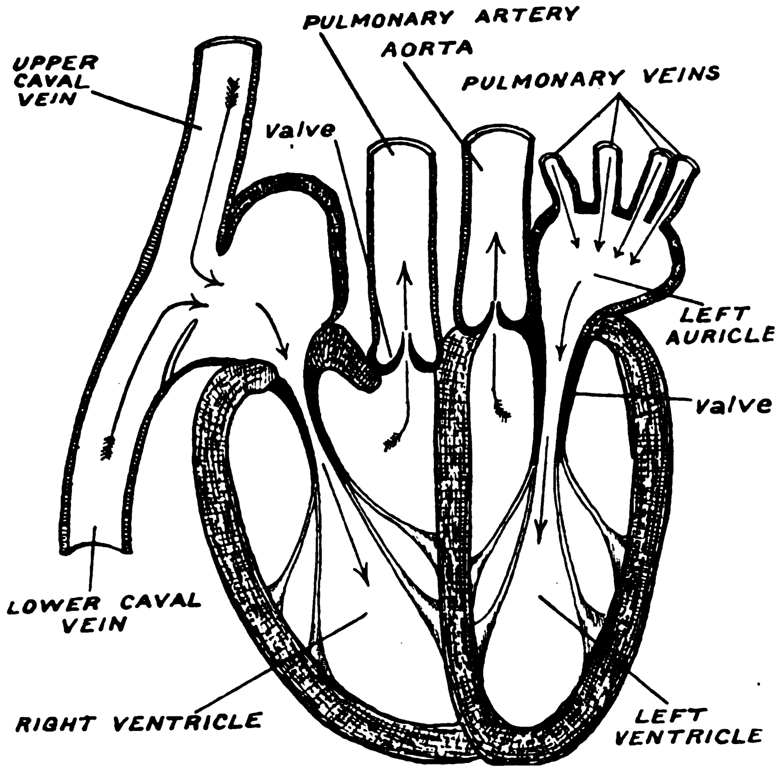
THE HUMAN HEART.

There are four chambers, two auricles or receiving chambers and two ventricles or driving chambers. The right auricle (R A) receives the impure blood from the body by two superior venæ cavæ (S V C) and one inferior vena cava (I V C).

The blood is passed into the right ventricle (R V), whence it is driven to the lungs through the pulmonary arteries (P A). From the lungs the purified blood returns by the pulmonary veins (P V) to the left auricle (L A).

From the left auricle it passes to the left ventricle (L V), whence it is driven up the systemic arch (S A) to the body. The systemic arch first gives off a right innominate artery (I N N), dividing into right subclavian and right carotid, to arm and head respectively. It then gives off a left carotid (C) and a left subclavian (S C L), to head and arm respectively. It is continued dorsally backwards to form the dorsal aorta (D A), the great artery distributing pure blood to the whole posterior body.

T R is the windpipe or trachea ; B R, a bronchial tube from the windpipe carrying air to the lungs ; B V, a blood-vessel on the wall of the heart itself.



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THE FOUR CHAMBERS OF THE HEART AND THE VALVES WHICH GUARD THEIR OPENINGS.

From the upper caval vein (superior vena cava) and the lower caval vein (inferior vena cava) the impure blood from the body enters the right auricle. It passes through an opening, bordered by a threefold (tricuspid) valve (dark) into the right ventricle. The membranous flaps are worked by tendinous strings (chordæ tendineæ) attached to papillary muscles projecting from the wall of the ventricle.

From the right ventricle the impure blood is driven through the pulmonary arteries to the lungs, and the base of the pulmonary trunk is guarded by three membranous pockets, the semilunar valves.

From the lungs the pulmonary veins carry purified blood to the left auricle, whence it passes into the left ventricle through a funnel-like opening guarded by a mitral valve with two membranous flaps, worked by strings and muscles as before.

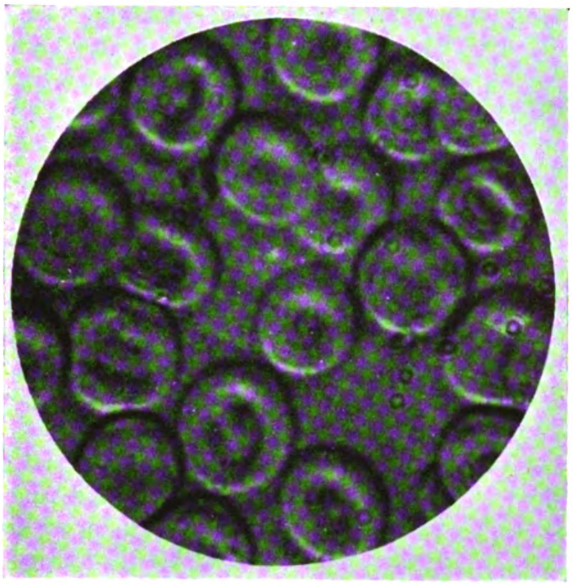
From the left ventricle the pure blood passes by the aorta to the body, and the base of the aorta is guarded by three semilunar valves. The meaning of the whole system of valves is to keep the blood flowing in the right direction.

sea-water, taking our thoughts back to the time many millions of years ago when blood was first established as an internal medium in animals living in a primæval sea. In the blood plasma there float enormous numbers of single cells or corpuscles. A minority of these are the "white" corpuscles, many-sided old-fashioned cells not very unlike simplest amœboid animals in their power of independent movement and of engulfing solid particles. But the great majority of the blood-cells are the "red blood corpuscles," of which there may actually be thirty million million in man's body—several millions in the smallest drop of blood. These are disc-like cells, specialised to one particular purpose, the carrying of the complex red pigment or colouring matter of the blood, the *hæmoglobin*. The blood as a whole has several very special properties, such as the power of preserving its neutrality and almost never becoming harmfully acid or alkaline, and the power of forming clots instead of escaping when the walls of its containing vessels are broken.

Functions of the Blood.

The first great function of the blood is a simple and obvious one. It receives from the cells which line the intestine large quantities of food materials, digested and absorbed, which it carries throughout the body to be burned in the cells. First of all, however, the blood runs from the intestine to the liver, which is the great "clearing-house" of the body, and has a controlling influence on all the three great classes of food-stuffs. In particular it takes up the absorbed simple sugar, and stores it in the form of the complex "animal starch" or glycogen. From these stores it doles out sugar into the blood as the body requires it, so that the amount in the blood is always very much the same. Stores of glycogen are also formed in muscle tissue, and fat is stored similarly in various parts of the body. There are no stores of protein, except in the living tissues themselves, yet in starvation the sugars and fats are used up first and the protein is preserved as long as possible. Hence we believe that the nitrogen-containing proteins are, of the three classes of foods, the most fundamentally essential to life.

No fire burns without air and no cell can live without oxygen. We have seen this already, and it is well to insist upon it. In all the highest animals the oxygen comes from the air. Some simple forms seem to be able to manufacture



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RED BLOOD CORPUSCLES OF MAN.

Each cell or corpuscle is a circular disc, on an average about $\frac{1}{3200}$ of an inch in diameter, and about one-fourth of that in thickness. More than a million will lie on a square inch. The disc surfaces are not flat, but slightly concave; so the corpuscles are thinner in the middle than at the margin. Their colour is faint yellowish-red, due to the pigment hæmoglobin, which has a great affinity for oxygen. The mammalian red blood corpuscle does not show any nucleus except in the early stages of its development. The white blood corpuscles are larger, nucleated, and irregular. The red blood corpuscles are mostly made in the marrow of the bones and mostly destroyed in the liver and spleen.

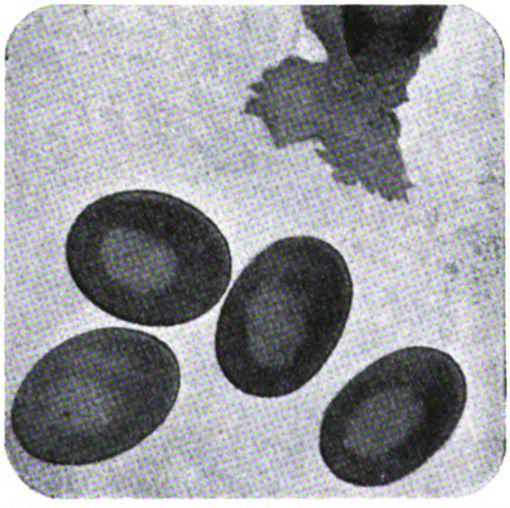
it for themselves—by splitting up carbon-dioxide or something else; the humbler aquatic animals, like shrimps and oysters, fishes and tadpoles, find it dissolved in the water; but the higher aquatic animals, like turtles and sea-snakes, seals and whales, must at frequent intervals come up to the surface to breathe.

Breathing.

Respiration in the broadest sense must always mean taking in oxygen and getting rid of carbon-dioxide, the waste product of all combustion—including vital combustion, There are many animals without blood, e.g., sponges, jellyfishes, corals, zoophytes, and the simplest worms; and these must, of course, respire, in the sense that they must take in oxygen and get rid of carbon-dioxide.

But in animals with blood, breathing is the process of charging the blood with oxygen. The gills of a fish are organs so thin-walled that oxygen can pass through to the blood from the water outside. The lungs of a mammal are bellows with enormous internal surfaces with very delicate walls through which gases can diffuse. The movements of breathing are the movements required to draw fresh air into the lungs and to force used air out of them. Although in the ordinary way we are not conscious of these movements, and do not have to command each one to take place, they are not automatic as the movements of the heart are. Messages are continually sent to the muscles which expand the chest by a special "respiratory centre" of the brain. In general the frequency of these rhythmic messages is decided by the state of the blood, to which the respiratory centre is very sensitive. But the centre will also obey the messages from higher levels of the brain, as when we voluntarily hold our breath, or from the nerves of the body, as when we gasp at a pin-prick. At each message from the respiratory centre, muscles contract, the chest expands, and about a pint of additional air is drawn into the lungs; the return of the chest to its original size is automatic.

Through the thin wall of the lungs oxygen passes into the blood; some of it dissolves in the fluid plasma, but a much larger part combines chemically with one special constituent, the colouring matter, hæmoglobin, which is carried by the red corpuscles. The corpuscles, with their temporary load of oxygen, are borne to



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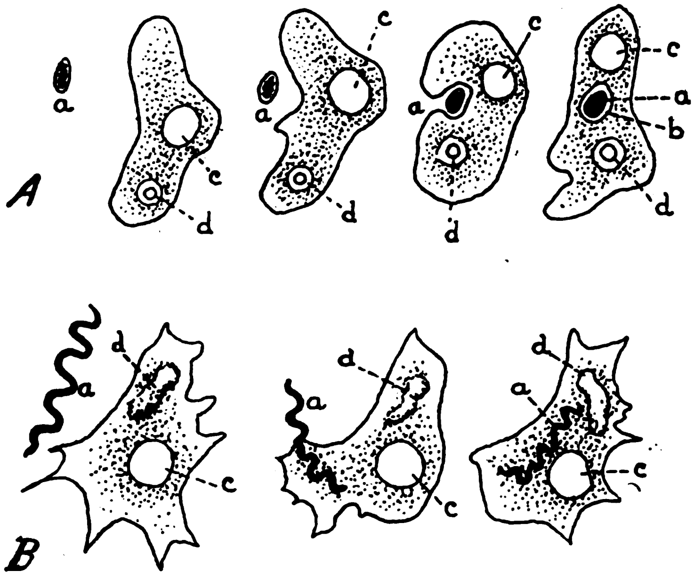
FOUR RED BLOOD CORPUSCLES AND A WHITE CORPUSCLE OF A FROG; THE LATTER HAS ENGULFED A WORN-OUT RED BLOOD CORPUSCLE.

(Magnified 600 diameters.)

The frog's red blood corpuscles (or erythrocytes) differ from those of man and mammals in having a persistent nucleus. They are biconvex elliptical discs, considerably larger than the biconcave circular discs characteristic of mammals. It may be noted that in the family of camels the red blood corpuscles have the elliptical outline seen in birds, reptiles, amphibians and fishes.



(A) THE MINUTE ANIMAL CALLED AMŒBA COMPARED WITH (B) A PHAGOCYTE OR COLOURLESS CORPUSCLE OF THE VERTEBRATE'S BLOOD.

In both cases a food-particle *a* is seen, and its "engulfing" in the living protoplasm of the microscopic cell—there to be dissolved and digested by "enzymes" or "ferments"—is shown. The food-particle here taken up by the Phagocyte is a kind of microbe, a Spirillum. It is digested and destroyed. *b*, water surrounding the food-particle engulfed by the Amœba; *c*, a vacuole or liquid-holding space in the protoplasm; *d*, the cell-nucleus.

the heart and thence throughout the body; in the delicate capillary vessels the hæmoglobin parts with its oxygen to the surrounding tissues. The corpuscles return through the heart to the lungs and take up fresh loads of oxygen. There is continual coming and going between the place of oxygen-capture, the lungs, and the place of combustion, the tissues.

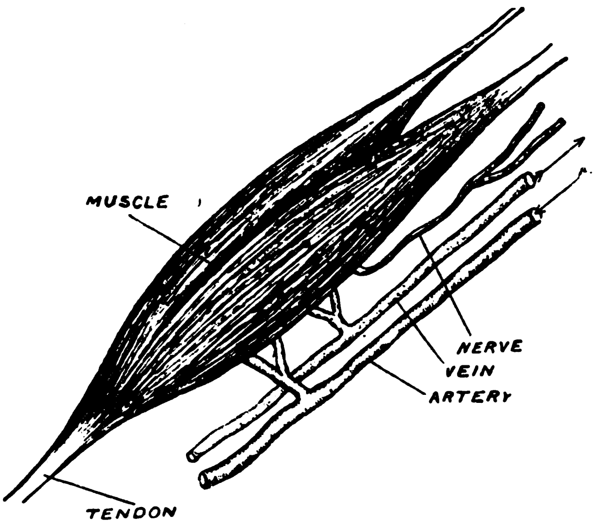
We see, then, that the blood brings to the cells of the body from the intestine food materials for tissue-building and especially for fuel, and from the lungs oxygen to combine with this fuel in the burning of the fire of life. The final results of this burning are, as we have seen, water and the gas carbon-dioxide. Both of these find their way from the tissues into the blood in the capillaries. From the blood the water escapes as vapour through the skin or through the walls of the lungs, or is removed from the blood by the kidneys or elsewhere. Nearly all the carbon-dioxide, however, is carried by the blood to the lungs, and here passes through the thin wall and is breathed out. This is the other side of the process of breathing—the getting rid of the carbon-dioxide produced by the body. In the blood it is carried not so much by the corpuscles as dissolved or combined in the fluid plasma. If it accumulates unduly in the blood the sensitive respiratory centre of the brain responds and sends to the lungs messages calling for another or deeper breath.

§ 4

THE MUSCLES

IN an ordinarily active animal a great deal of the chemical fuel and oxygen brought by the blood is used up by the muscles, where the chemical energy of the food materials is converted into energy of motion. Even during sleep, the beating of the heart, the expansion of the lungs, and the slow movements which force the food down the alimentary canal, go on steadily and have to be maintained, though they require no conscious control. There are different kinds of muscle: those which are directly under the control of the will, typically quick and powerful in action, as for example in the limbs, have a striped structure, and are seemingly more complex than the more sluggish plain muscles which move the internal organs. The heart muscle, with its innate capacity for rhythmic beating, is different from both. The striped muscle may be selected for more detailed description.

Muscle has as its chief characteristic *stringiness*. Everyone is familiar with the "grain" of most meat, and the microscope reveals a subdivision into finer and finer parallel fibres. Each fibre consists of one or several cells, though very unlike the generalised Amœba-like type, since they are long and very narrow; and within each fibre are finer "fibrils." When a muscle is



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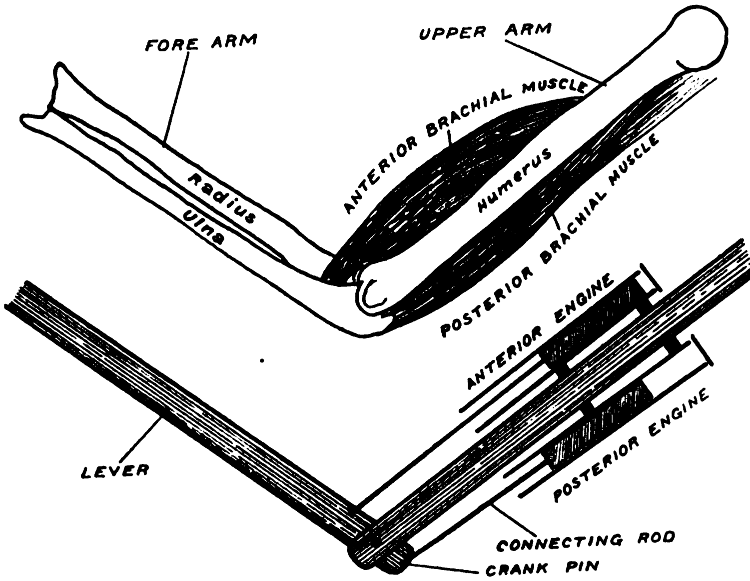
A DRAWING OF THE BICEPS OF THE UPPER PART OF THE RIGHT ARM, SHOWING ITS TENDON, ITS BLOOD-VESSELS AND ITS NERVE.

A tendon or sinew fastens a muscle to a bone; the artery brings oxygen and food-material for the muscle; the vein carries away carbon-dioxide and waste; the nerve conveys the stimulus which provokes the muscle to contract. The biceps lies along the upper arm or humerus: its upper end is connected by two tendons with the shoulder-blade or scapula; its lower end is connected by a tendon with the radius, one of the bones of the lower arm; when the biceps contracts, becoming shorter and broader, as we can feel it doing, it raises the lower arm nearer the upper arm.

stimulated, normally by a message running down the nerve which controls it, or artificially by an electric shock or otherwise, the fibres become shorter and thicker, and the whole muscle contracts in length but becomes wider in proportion: the volume remains the same. If the stimulus is a weak one, only a few fibres may contract, but each fibre, once started, contracts as far as it can. It may not seem clear how contraction can produce all the movements with which we are familiar, bending and straightening the limbs, for example, but this is managed by lever-like arrangements, to which we shall return later on. The muscles of the limbs are fixed at their ends by *tendons* to the bones, and their contractions pull the bones closer together.

A muscle can be artificially connected up with levers so that it draws a record of its movements on a smoked paper, and in this way the contractions can be studied. After a stimulus is sent down the nerve which controls it, there is a brief "latent period," during which nothing happens. Then the muscle contracts swiftly, a wave of contraction passing down the fibres, and as swiftly it relaxes to its original position. But if, after many such contractions, the muscle becomes fatigued, then its response to the stimulus is greatly weakened. It does not contract nearly so much, and it takes much longer to regain its original position; great cold and certain poisons have a similar effect. If one stimulus follows another very closely, the muscle may not relax in between, but remains for some time in the shortened state.

Muscle fibres are elastic, and can be pulled out to abnormal lengths. In this way they resemble springs, but they are springs which, when they receive a stimulus, suddenly tend to become much shorter than in their normal



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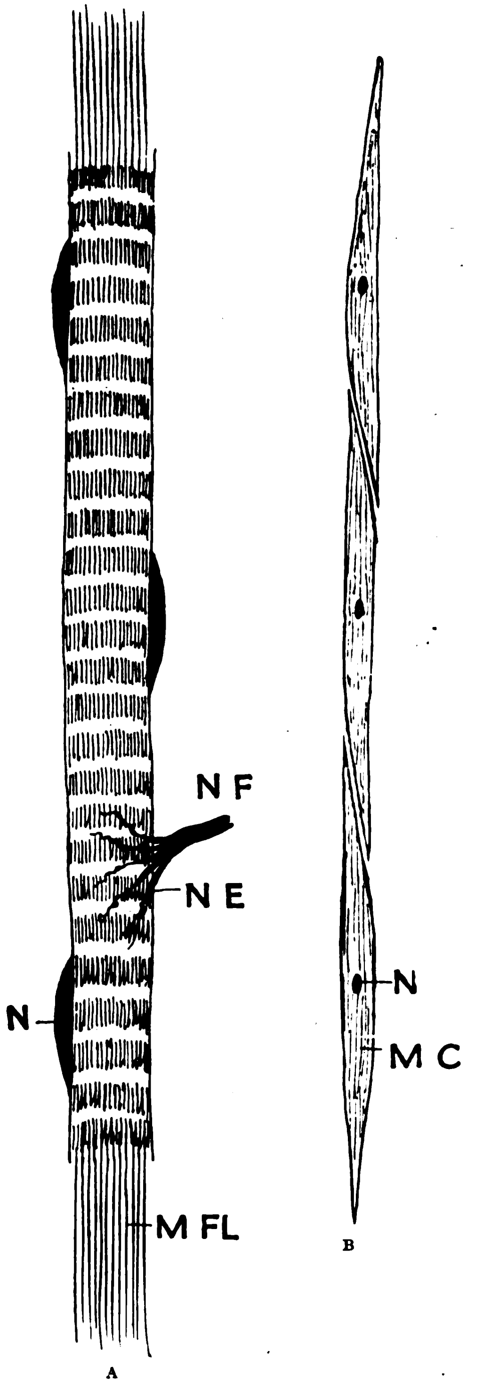
THE ENGINES OF MAN'S ARM.

The upper figure represents the two great muscles of the upper arm or humerus, the engines which move the lower arm. The anterior brachial or biceps pulls on the fore-arm and bends it at the elbow. The posterior brachial or triceps straightens it again. In the lower figure the muscles have been imaginatively replaced by two internal combustion engines, which work in perfect time with one another, as the muscles do. When the piston of one is ascending that of the other must be descending. The connecting rod would correspond to a tendon.



TWO KINDS OF MUSCLE-FIBRES, STRIPED OR STRIATED, AND SMOOTH OR PLAIN.

A. A striped or striated muscle-fibre, quickly contracting, showing alternate dark and light cross-bands. It is built up of very delicate fibrils (M FL). It is stimulated by a nerve-fibre (N F), which divides into an end-plate (N E) on the contractile substance. A striped muscle-fibre is due to the great elongation of a cell, with multiplication of nuclei (N), or sometimes to a fusion of several elongated cells.

B. Three smooth or unstriped muscle-cells (M C), elongated spindles, dovetailed into one another, each with a nucleus (N). There may be longitudinal fibrillation. Smooth muscle-cells are slowly contracting. They occur in such situations as the wall of the food-canal, the wall of the bladder, the wall of the arteries; and abundantly in sluggish animals, such as sea-squirts.

resting state. What is the change caused by the stimulus which makes the spring-like fibres "dissatisfied," so to speak, with their usual length, and attempt to contract?

It is only in the last few years that satisfactory answers to this question have been available, but now a fairly complete story has been worked out. When a nerve-message reaches a muscle, it causes the formation of lactic acid, almost the same as the acid of sour milk. Everyone knows the astringent, puckering effect of swallowing anything sour, and the muscle fibre feels it too, and in the presence of lactic acid it contracts. What the lactic acid is formed from is not certain, but it must be some member of the sugar family, and it must always be present in muscle. In any case, the contraction has now taken place, and so far, let us note, there has been no "burning" or oxidation, no using up of material.

But to enable the muscle to return to its original condition, the sour lactic acid must be got rid of. Till this is done the story is only half told. The most economical way to get rid of the lactic acid is to change it back into the substance from which it came, and, as far as possible, this is done. But this is a building-up process, a synthesis, and it requires energy to carry it out—energy which must be furnished by some process of burning or oxidation. The solution is a neat one: a small part of the lactic acid is burnt to carbon-dioxide and water, and this burning furnishes enough energy to convert the rest of the lactic acid back into its unknown source-substance or "precursor." The muscle is then able to return to its original state, and it is the return, not the contraction, which requires a supply of energy. In the same way, a piece of elastic may contract spontaneously, but it requires energy to pull it out again into its original taut condition, though the story of muscle contraction is not quite so simple as that. It seems likely that fatigue of muscles is due to lactic acid accumulating and not being thoroughly removed.

When a muscle contracts, a certain amount of heat is generated, and an electric current is also set up. Both these require energy, which is, as far as we can see, more or less wasted: the efficiency of a muscle is not quite perfect. Yet the whole process, whereby a sugar yields an

acid that causes a fibre of protein to contract, and the acid sacrifices a part of itself to convert the rest back into the sugar so that the protein may return to its former state, is a marvel of interaction and economy that "puts to scorn all machinery."

Animals often anticipate man, not only in what they do and how they do it, but in having structures that are like human tools. In some cases the animal structure may have suggested the human tool, but there is not much evidence of this. In the construction of aeroplanes and gliders, some experimenters have been humble enough to study the flight of insects or birds, or the sailing of the dragon-fly and the albatross; but there are not more than a few human inventions which can be shown to have been suggested by Natural History. Perhaps there would have been more if the study of animal life had come earlier to its own. We firmly believe that there is fame and fortune awaiting the man of inventive genius who will condescend to study animal achievements. Why should the firefly beat us in solving the problem of the most economical illumination? Many animals have tool-like structures as parts of their body: the lobster has its forceps, the wood-wasp has a very effective borer, the sea-urchin has little snapping organs like three-bladed scissors, the leech has its adhesive sucker, the sawfish its saw, the beaver its chisel-edged teeth, the angler fish its rod and baited line.

A bird has an interesting pulley by means of which a muscle on the breastbone *raises* a wing above the back. It seems strange that a muscle on the under surface of the body should, by its contraction, raise the wing, but we see the same when a sailor on the deck of a ship causes a sail to rise by pulling a rope downwards. In both cases the explanation is to be found in the presence of a pulley. The rope in the bird is the tendon of the muscle, and it works through a pulley, the foramen triosseum, where three bones meet.

There are not any wheel-like mechanisms among animals, but there are plenty of levers.

Levers of the Body.

We suppose that they simply had to be, for in moving the body and moving other bodies, the most effective arrangements are levers. No doubt they were somewhat rough-and-ready to begin with in the animal body, but in the course of millions of years of varying and sifting they have become very perfect. As everyone knows, levers are divided into three classes according to the position of the fulcrum. To move a felled tree we may press the lever down on a fulcrum—a solid, fixed support on the ground near the tree. We are familiar with the same leverage when one child lifts another on the see-saw. The fulcrum is between the weight and the power. We illustrate this in our body when we use the foot to push the pedal of a harmonium or a sewing machine, or when we nod the head backwards and forwards on the first vertebra or atlas which serves as the fulcrum.

In raising a large flat stone the workman sometimes gets in the end of his lever, and, pressing against the hard ground, lifts hard at the other end. The fulcrum is at one end of the crowbar, where it is pressed into the hard ground, and it is nearer to the weight than to the power. This is a lever of the second class, and is illustrated when we stand on tiptoe: the weight of the body, falling on the ankle, is raised by the contraction of a group of muscles, mainly the hamstring or calf muscles above the heel; the fulcrum consists of the balls of the toes, which press against the ground. Another lever of this type is illustrated when we keep one thigh bent up towards the body in hopping: the fulcrum is at the hip-joint, the power, due to the contraction of the muscles in front of the thigh, is applied at the knee; the weight of the limb falls between the two.

In whipping a trout out of the water with a fishing-rod, the fulcrum is the heavy end of the rod, which may be pressed against the angler's body; the power is applied by the hands a little higher up; the weight is the trout. In levers of this third class, the fulcrum is at one end, but nearer to the power than to the weight. When we lift a cup of coffee to our mouth we illustrate this kind of leverage. The fulcrum is at our elbow joint, the weight is the forearm, the hand, and the cup, and the power is due to the contraction of the biceps muscle lying in front of the upper arm, but this power is exerted a little below the elbow, where the tendon of the muscle is fastened to the radius bone of the forearm. This kind of lever allows of great rapidity of action, and is familiarly exerted in

striking a tennis ball.. When a dog bites, it illustrates the same third kind of leverage: the power of the contracting muscles is applied to the lower jaw between the jaw-hinge and the weight, which is that of the jaw and teeth, but must include the resistance which the object bitten offers to compression. We have given very simple instances, but enough to show how more complex leverages in our body may be tackled. The snake's jaw, for instance, with its many hinges and sliding movements, is a very much more complex problem than the dog's.

§ 5

THE NERVOUS SYSTEM AND THE SENSES

THE twigs of the great branching tree of the nervous system reach into every part of the body. They lead at last to a central stem, the spinal cord, enormously developed in the head, in the higher animals, to form the brain, the seat of the highest activities of the nervous system, such as binding the body into a harmonious whole, and of the mind, such as judgment. The nervous tissue, like any other, is made up of cells, which are specialised for one particular purpose—*communication*. All the nerve cells have issuing from them branching fibres which link them to their neighbours, and many have one main fibre which may be several feet long. These fibres serve to carry messages to or from the centre, the brain and spinal cord, and the visible strands of nerve are bundles of such fibres.

The whole system may be divided into two parts, one having to do with messages towards the centre, the other bearing messages outwards from the centre. No single fibre ever does both of these things. The two sides of the question are linked together at various levels, simply in the spinal cord and more complexly in the brain.

Reflex Actions.

Suppose that the sole of the foot is tickled, or touched with something unpleasantly hot or unpleasantly cold. The sensitive nerve-endings in the skin record the fact, and a message speeds up the sensory nerve fibres towards the centre. A moment later a message comes from the centre to the muscles of the leg, which obediently contract, so that the knee is bent and the foot removed from the source of irritation. This kind of response is a very simple one: it does not require the intervention of the brain at all. One of the linking cells in the spinal cord has received the incoming message and despatched the command to the muscles: this is known as a *reflex* act.

Scout-Cells, G.H.Q.-Cells, Executive Officer-Cells.

The analogy of an army is a useful one. If the scouts report a disturbance which is not serious and may be dealt with quite simply, the necessary action may be taken by (let us say) the brigade headquarters—the linking cell in the spinal cord. A more complicated affair may have to be referred to the divisional or even to general headquarters—the brain; and may, indeed, require the exertion of conscious intelligence or even abstract reasoning. Even in the case of a simple disturbance such as we have described, commands from higher up may forbid the local authorities taking the action they otherwise would—that is to say, conscious or unconscious commands from the brain may prevent a reflex response to

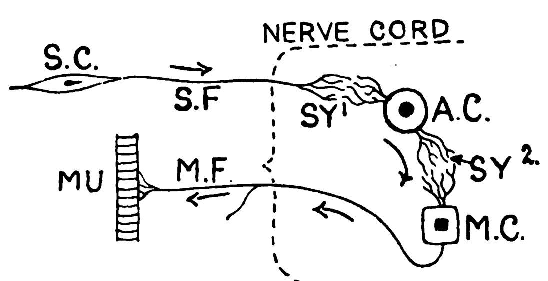


DIAGRAM OF A SIMPLE REFLEX ARC IN A BACKBONELESS ANIMAL LIKE AN EARTHWORM.

1. A sensory nerve-cell (S.C.) on the surface receives a stimulus.
2. The stimulus travels along the sensory nerve-fibre (S.F.).
3. The sensory nerve-fibre branches in the nerve-cord.
4. Its branches come into close contact (SY^1) with these of an associative or communicating nerve-cell (A.C.)
5. Other branches of the associative cell come into close contact (SY^2) with the branches or dendrites of a motor nerve-cell (M.C.).
6. An impulse or command travels along the motor nerve-fibre or axis cylinder of the motor nerve-cell.
7. The motor nerve-fibre ends on a muscle-fibre (M.F.) near the surface. This moves and the reflex action is complete.

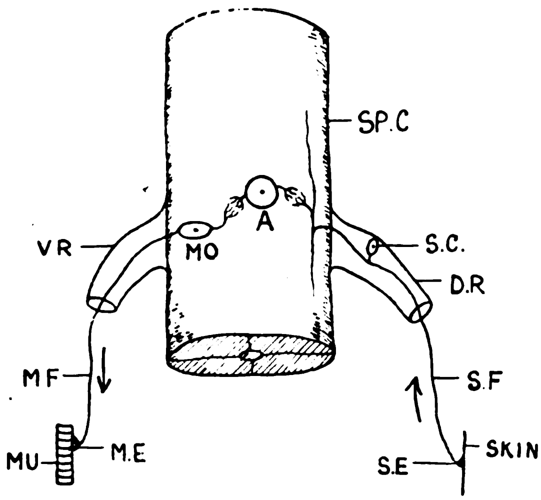


DIAGRAM ILLUSTRATING REFLEX ACTION IN MAN OR ANY BACKBONED ANIMAL.

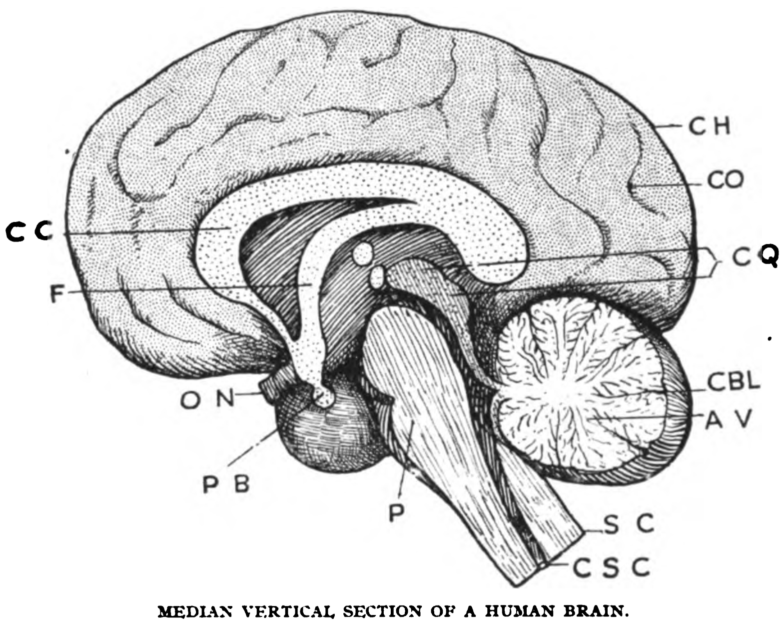
From a sensory nerve-ending (S.E) in the skin, a stimulus passes up a sensory nerve-fibre (S.F) to a sensory nerve-cell (S.C.) in the spinal ganglion of a dorsal or afferent root (D.R) of a spinal nerve. The fibre, continued from the sensory nerve-cell, divides in the spinal cord (SP.C), and the message passes on to an associative, intermediate, or internuncial nerve-cell (A). Thence it is shunted to a motor nerve-cell (MO), from which a command passes down a motor nerve-fibre (M F), issuing by a ventral or efferent root (V R) of a spinal nerve. The motor nerve-fibre ends in a nerve-plate (M.E) on a muscle-fibre (MU), which is stimulated to contract. Then the reflex action is complete.

command them to act, or to cease from acting. There are nerves, too, which cause the muscles that *straighten* the leg to slacken as the muscles that *bend* the leg contract. The heart beats of itself, but messages travel to it by different nerves to say " slower " or " faster." Nor is it absolutely necessary that the messages should come from the mysterious activity of the linking cells of the brain or the spinal cord; it is sufficient in experiments to pinch or to shock electrically one of the out-going nerve fibres to cause the muscle it commands to respond.

For all that, we know next to nothing about the nature of the impulse that travels along nerves. An electric current accompanies it, as it does all the activities of living matter, but the impulse is much slower than electricity. The nerve fibre never seems to tire as muscle tires. The chemistry of nervous tissue is complex and difficult, and the most we can say certainly is that in nerves, and especially in the brain, the fire of life burns brightly if eerily, since a great deal of oxygen is used up. Of the relation

any irritation or stimulus. Even when a stimulus has been effectively dealt with by the " local authority " in the spinal cord, by commanding the proper reflex response on the part of certain muscles, a " report " both of the nature of the irritation and the response may reach the brain. We *know* very well when we have touched a hot plate, but our hand is *reflexly* withdrawn before the brain has time to issue any commands. It is only by preparing ourselves beforehand that we can overrule the "local authority" and prevent the reflex withdrawal, if we wish to handle anything unpleasantly hot.

The outward messages are not restricted to commanding the muscles to contract. Some of them go to glands, such as those which pour the saliva into the mouth, and



MEDIAN VERTICAL SECTION OF A HUMAN BRAIN.

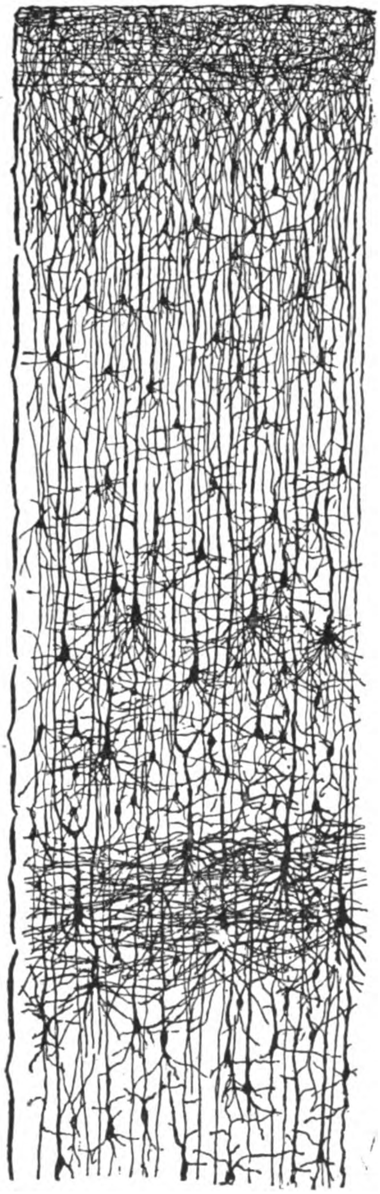
In every vertebrate brain there are five chief parts: the cerebral hemispheres (C H), here with convolutions (CO); the optic thalami; the optic lobes (C Q), in mammals "corpora quadrigemina"; the cerebellum (CBL), with an internal pattern called arbor vitæ (A V); and the medulla oblongata (behind P) leading into the spinal cord (S C).

C C, the corpus callosum, a transverse bridge of fibres, uniting the cerebral hemispheres. F is a longitudinal bridge of fibres, called the fornix. It makes the roof of the optic thalami region, or third ventricle. Behind the fornix are seen two transverse commissures cut across.

C S C, the cerebro-spinal canal continued down the centre of the spinal cord (S C).

P, the pons varolii, a bridge forming a sort of transverse floor to the cerebellum. Behind P is the " bulb " or medulla oblongata.

P B, the pituitary body, a nervous and glandular body growing down from the floor of the optic thalami region. O N, one of the two optic nerves.



From Quain's "Anatomy," by the courtesy of the publishers, Messrs Longmans, Green & Co. Ltd.

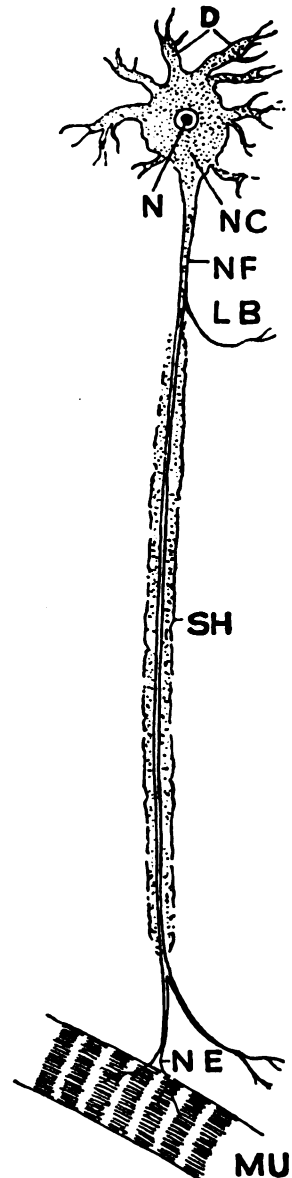
NUMEROUS CELLS WITH THEIR INTERLACING FIBRES FROM THE HUMAN CEREBRUM OR FORE-BRAIN (Highly magnified.)

The fore-brain or cerebrum is the seat of the intellectual processes, and the sight of these crowded nerve-cells, each with its many linkages with other nerve-cells, gives a hint of the possibilities of inter-relation among the millions of cells in the brain. There is no increase in the number of nerve-cells after birth, but new inter-relations may be established.

between the mental activities and the physical appearances of the brain we dare say nothing, except that "mind" and "brain" are closely bound up together, some would say like the two surfaces of a dome, others would say like a musician and his instrument. In some cases we know that certain parts of the brain have to do with particular mental activities.

It is fortunately possible to be more definite about the various organs of sense. Not all of these receive their stimulus from outside the body: some report to the brain the movements and condition of the muscles, joints, and internal organs. The whole surface of the body is an enormous sense-organ, or perhaps better a mosaic of different sense-organs. For there are "pain-spots," "touch-spots," "cold-spots," and "heat-spots" in the skin, quite separate from each other, each able to create only one kind of sensation in the brain, and capable of being mapped out on the surface of the skin. The "chemical senses" are restricted in man to the mouth and nose. There are really only four kinds of taste—sweet, bitter, salt, and sour—and these are excited only by dissolved substances in the mouth. The innumerable "flavours" are really appreciated by the sense of smell, which is stimulated by gases or very minute particles. The sense of smell is, even in man, extraordinarily delicate, and is easily fatigued. But our knowledge of the organs of these senses is not so complete nor so informing as our knowledge of the eye and of the ear.

Sense-Organs.



A SINGLE NERVE-CELL OR NEURONE. (After Stöhr.)

The nervous system is made up of nerve-cells and their outgrowing fibres. The technical word neurone includes both the cell-body and the outgrowths. N is the nucleus of the cell; N C, the central cell-substance or cytoplasm. The nerve-cell communicates with other nerve-cells by means of fine protoplasmic branches or dendrites (D). It gives off a nerve-fibre (N F) to a muscle (MU). This fibre has as its essential part an axis cylinder or core, surrounded by a medullary sheath (SH) of a fatty material; and outside this there is a clear membrane called the neurilemma. It will be observed that the medullary sheath is not developed at the origin or at the end of the nerve-fibre. A lateral branch of the fibre is shown (L B) and also the nerve-ending (N E) on the muscle.

The Ear

Many kinds of ears are balancing organs which do not hear; and even in birds and mammals, where hearing is usually acute, the balancing function is still very important. For many backboneless animals it is certain that the ear enables the animal to move about in a balanced way. If something puts it out of action, the animal will swim on its back or tumble about in a random fashion. Before the ear was a hearing organ, for the receipt of sound, it was an organ for balancing or equilibrium, and, as we have said, the primary use persists.

To nine people out of ten the word ear suggests in the first place the ear-trumpet or pinna, which is restricted to certain mammals. The use of the trumpet is to collect the waves of sound and facilitate their location, and since man has a very mobile head, his pinna is comparatively small. It is interesting to see how a horse waiting in the street locates a sound by moving its ear-trumpets without moving its head. The ear-trumpet is often very large in mammals that hunt at night, like bats and half-monkeys or lemurs, and the jerboas in the desert. It is absent in burrowers like the mole, and in aquatic mammals like the porpoise. Probably the elephants are the only wild mammals that have their ear-trumpets hanging down, but it is interesting to notice that this ineffective position is common among domesticated animals, like the lop-eared rabbits, and dogs and sheep, which are, of course protected under man's shield. In aquatic mammals the water is kept out of the ear-passage in various ways; thus the otter has a valve, and in seals the outer ear-passage runs for a short distance

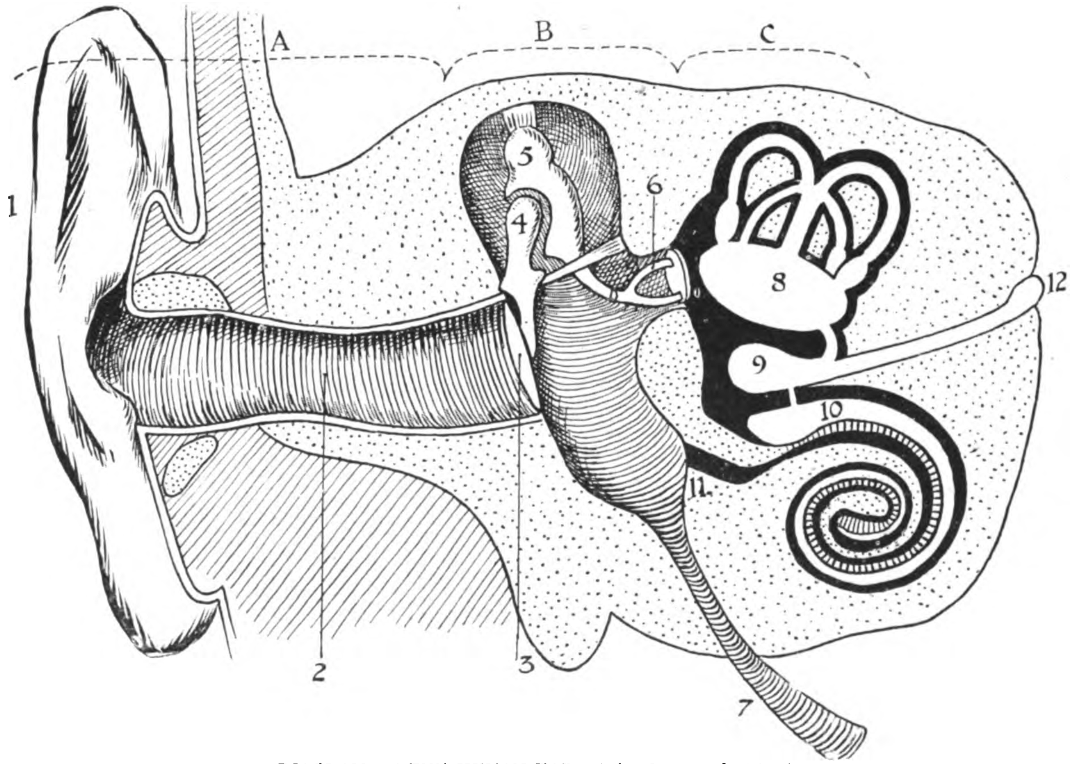


DIAGRAM OF THE HUMAN EAR. (After Hesse and Weber.)

A, the outer ear-passage; B, the middle ear; C, the bone (periotic) enclosing the inner ear.

1. The ear-trumpet or pinna, practically fixed in man and unimportant. In many mammals, such as the horse, it helps to locate the sound. 2. The outer ear-passage with the drum or tympanum (3) running across its inner end. The drum vibrates when sound-waves strike it. 4, 5, 6. The ear-ossicles, hammer (malleus), anvil (incus), and stirrup (stapes), which by their movements transmit the vibrations from the drum to the inner ear. In fishes these delicate ossicles are represented by biggish bones, forming part of the commonplace framework of the jaws. Only mammals have three ear-ossicles; birds, reptiles, and amphibians have one; fishes have none. The "window" in the bony wall of the inner ear on which the stapes abuts is called the fenestra ovalis. 7. The Eustachian tube, leading down to the back of the mouth; by it air can enter indirectly into the middle ear. 8. The larger chamber of the inner ear, called the utriculus, with three semicircular canals arising from it. They have to do with balancing and the like. 9. The smaller chamber or sacculus, connected with the coiled cochlea, the essential organ of hearing (10), containing the organ of Corti. There is also shown the endolymphatic duct (12), which ends blindly. 11. Another "window" in the periotic bone, the fenestra rotunda. The dark-coloured cavity is called the perilymph-space; it contains a fluid called perilymph; it is separated from the internal cavity of the ear by a membrane, within which there is endolymph. The dotted tissue is bone.

under the skin, parallel with the surface of the skull, so that it is closed in swimming and diving by the pressure of the water. If the water got into the ear-passage down to the drum, the animal could not hear at all. Bathers know this experience of temporary deafness.

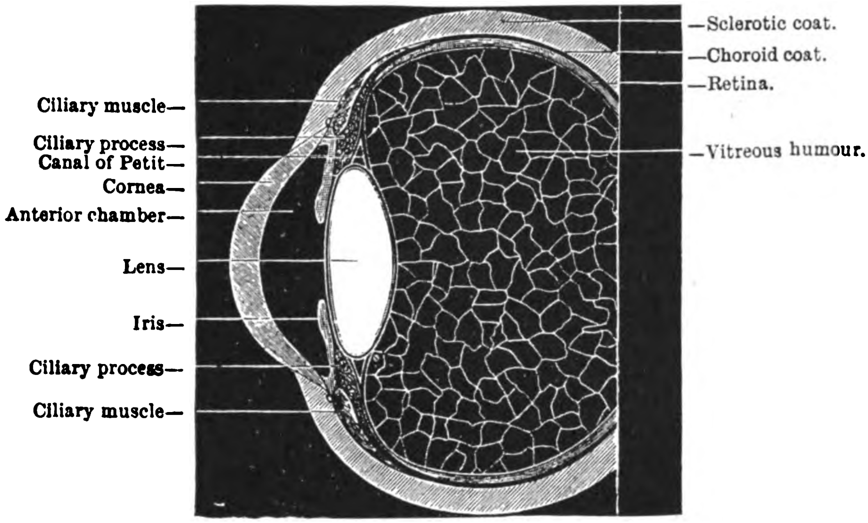
The tense membrane (the tympanum or drum) which is stretched across the outer ear-passage, is a mechanical device for receiving sound waves. It makes its first appearance in amphibians, and we see it, flush with the skin, just behind the frog's eye. This is an effective position for catching the sound-waves, but it is a dangerous position, since the drum is exposed to injury. It is not surprising, therefore, that in the higher animals it has sunk beneath the surface. But there is surely interest in noticing that, in the new-born American monkey, the drum of the ear is still in its old superficial position, flush with the surface. As the organ of hearing in backboned animals is an extraordinarily delicate instrument, it is important to have it deeply situated and within strong ramparts. But this means that it lies at some distance from the vibrating drum. It is therefore necessary to have some way of transmitting the movements from the drum to the inner ear, and that is effected in mammals by a beautiful chain of three small bones—the hammer, the anvil, and the stirrup, the innermost of the three abutting on a minute window into the inner ear. This is a very pretty contrivance. When we are taken rapidly down the shaft of a deep mine (we tried one of about 6,000 feet near Johannesburg) we feel an uncomfortable pressure on the drum of our ear, and we are instructed to make a swallowing movement, which puts things right. Now, in this case, we are utilising a passage called the Eustachian tube, which runs from the middle ear behind the drum to the back of the mouth. In making the swallowing movement we adjust the pressure on the inside of the drum to the pressure outside. This Eustachian tube turns out to be the equivalent of the first gill-cleft or spiracle of the skate. Thus we see again that the distant past lives on in the present; the apparently new is also the undeniably old. It should also be mentioned that the chain of three little bones is found in mammals only; in birds, reptiles, and amphibians there is a simple rodlet (columella) running from the drum to the inner ear, and transmitting the vibrations.

The Hearing Ear.

Well protected within ramparts of bone, the inner ear is an extraordinarily complex instrument. Inside a bony labyrinth lies a similarly shaped membranous labyrinth, bathed by a fluid called perilymph and containing another fluid called endolymph. This internal fluid oscillates according, so to speak, to the tapping movements on the window of the inner ear; and the movements of the fluid eventually stimulate certain sensitive cells with hair-like free ends, whence a nervous thrill passes to the brain, and we hear! The membranous labyrinth includes a portion called the utricle, which gives off three semicircular canals, lying in different planes, and a smaller portion called the saccule, from which arises a spiral, twisted like a snail-shell, and therefore called the cochlea. More than two thousand years ago Aristotle saw the cochlea of the ear, whose shape, he said, "is like that of spiral shells." But he had, of course, no idea that inside the spiral shell of mammals there lies an exquisite instrument, "the organ of Corti," which analyses the mixed vibrations which fall on the ear, and converts them into the nerve impulses, which pass by the fibres of the auditory nerve to the brain. In the organ of Corti in our ear there are thousands of fibres which probably vibrate like harp-strings, there are ten thousand rigid rods of Corti, and there are still more numerous hair-cells, with each of which there is intimately associated the end of one of the fibres of the auditory nerve. If we suppose that there are about 11,000 tones audible to the human ear, there are about as many ear-telephones to receive them. For we are fearfully and wonderfully made.

The Eye

Helmholtz once pointed out that the human eye, considered as an optical instrument, was by no means perfect. On the other hand, when we think of the way it combines great delicacy with everyday usefulness, we cannot withhold our admiration. We can understand why a student beginning with the human eye, and knowing nothing of the simpler types, should conclude that it is impossible to think of the natural evolution of so



From Halliburton's "Handbook of Physiology," by the courtesy of the publishers—John Murray.

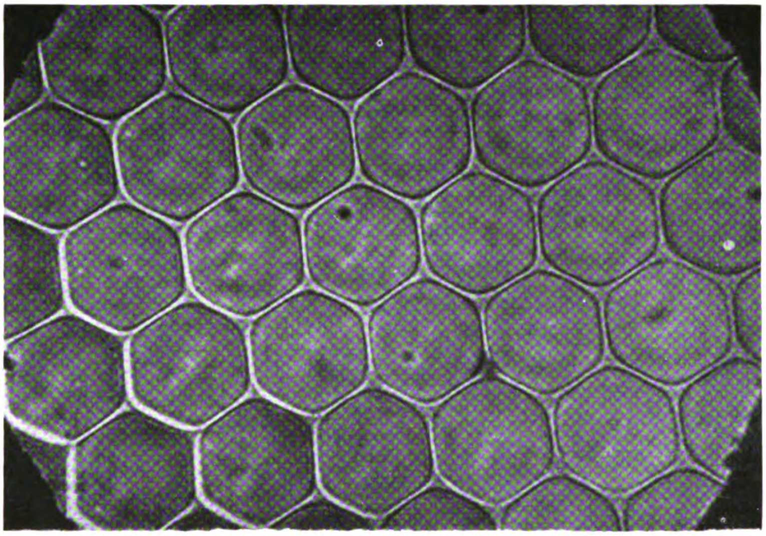
SECTION OF THE ANTERIOR FOUR-FIFTHS OF THE EYEBALL.

The ciliary muscle is a ring of muscle arising at the junction of cornea and sclerotic, the ciliary processes are radiating plaits passing from the choroid to the margin of the lens; the cornea is the transparent protective membrane in front of the eye; between it and the lens is the anterior chamber with aqueous humour; the lens serves to focus the rays of light, its outline is altered by the ciliary muscle; the canal of Petit is a minute canal round the edge of the lens; the iris is a fibrous and muscular continuation of the choroid in front of the lens and serves to regulate the admission of light; the sclerotic is the protective outermost layer; the choroid is a densely black layer with many blood-vessels; the retina is the innermost percipient layer, where the image is formed; the posterior chamber of the eye is filled with the glassy vitreous humour.

wonderful an organ. But the impression changes entirely when we take knowledge of the long series of eyes from the pin-points of a jelly-fish upwards. It is like studying an historical series of clocks showing the gradual improvement throughout centuries, with this difference, that instead of a succession of brow-wrinkling clock-makers there is a sequence of animals making unconscious experiments and then putting these to the test in the struggle for existence.

Helmholtz notwithstanding, the human eye is astonishingly perfect; but we cannot give more than representative samples of its many fitnesses. The eye is more or less spherical, so that it moves readily in its orbit, where it is well lubricated. It is a clear example of the unity of the whole series of backboned animals or vertebrates that in all well-developed eyes from fishes to man, there are the same six muscles attached to the skull at one end and to the outer wall of the eyeball at the other. A "rolling eye" usually means that these muscles are not very thoroughly under control; on the other hand, they may be trained to unusual efficiency, as in the case of some comedians. The lids protect the eye, and the upper one shuts down reflexly when some object is about to strike the surface. That it can also be moved voluntarily is familiar to all. In most mammals, such as the rabbit and dog, there is a well-developed third eyelid, present also in birds and some reptiles. This is drawn down over the surface of the eye, and has a cleansing function. It is absent in whales, where the front of the eye is continually washed with water. It is also absent in man and monkeys, and this may be because of the increased mobility of the upper eyelid. The distribution of tears over the transparent window in front of the eye is chiefly effected by the upper eyelid, and it serves to keep the pane clear. When a man "rubs his eyes" he is stimulating the lachrymal secretion and cleaning his window panes!

There is usefulness in comparing the eye to a photographer's camera. First of all, there is the case, rectangular in the photographic apparatus, globular in the eye. In some animals, as in crabs and lobsters, the eye is mounted on a stalk and can even look backwards. This stalk corresponds to the photographer's stand; but we must not delay over details. The camera is a dark, empty box; the vertebrate eye is a dark globe filled with the jelly-like vitreous humour, the pressure of which gives the eyeball a degree of rigidity which is quite essential. The camera gets that rigidity from the wood or metal of its framework. The vitreous humour in the inner chamber of the eye must be distinguished from the more watery aqueous humour which lies between the transparent window-pane (the

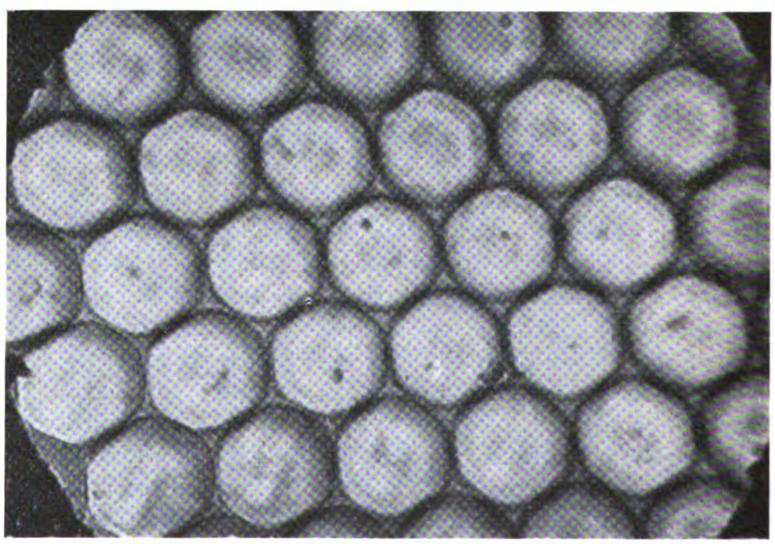


SURFACE VIEW OF A SMALL PART OF THE COMPOUND EYE OF A FLY, SHOWING THE NUMEROUS HEXAGONAL FACETS ON THE TRANSPARENT CORNEA.
(Highly magnified.)

To the inside of each facet there is an outer or corneal lens, inside that a crystalline cone or inner lens, and inside each of these a small group of percipient cells surrounding a sensitive rod, into the base of which there comes a delicate twig of the optic nerve.

cornea) and the crystal-clear lens. The firm protective coat of the eyeball, continuous with the strong cornea in front, is called the sclerotic; next comes the densely-black choroid, which is also rich in blood-vessels; inside that is the most important layer of all—the retina, which corresponds to the photographic plate. Though the retina is only the thickness of paper, it is built up of ten layers, and it is here that the image is formed. The most important elements, if we dare say so when all are important, are the rods and cones, which are the *light receptors*. One obvious advantage of the retina over the photographic plate is that it takes, so to speak, picture after picture without any confusion, whereas the plate in the camera can only be used once. Yet one of our retinal pictures, seen only for the twinkling of an eye, may be registered in the brain, or in our memory at any rate, for a lifetime.

The photographer often spends a tedious little while in focussing: he is trying to get a good definition of the image thrown on the plate by the lens. He effects this by altering the distance between the lens and the plate. Now, his lens corresponds to our lens, but the focussing is effected in a different way. In our eye it is largely effected by an alteration of the curvature of the front part of the elastic lens, making it more or less convex. This is brought about by means of (ciliary) muscle fibres, which are attached by a (suspensory) ligament to the transparent lens-capsule. And just as the definition of the image in the camera may be improved by using a small stop or diaphragm which regulates the amount of light that enters the instrument, so a delicate, self-acting muscle in the beautiful pigmented curtain or iris in front of the lens decreases the diameter of the aperture or pupil, and makes the image more sharply defined. There is also an adjustment of the two eyes so that the rays are focussed on the most sensitive part of the retina of each.



SURFACE VIEW OF A SMALL PART OF THE SAME EYE, SHOWING THE CORNEAL OR OUTER LENSES FITTING AGAINST THE HEXAGONAL FACETS. (Highly magnified.)

In the house-fly there are about 4,coo facets, corneal lenses, crystalline cones, and groups of percipient cells. Each series (facet, cornea, cone, group of percipient cells) makes an eye-element or ommatidium. Since the groups of percipient cells form an image and correspond to our retina, each is called a retinule; and the sensitive rod they surround is called the rhabdom.

Specially drawn for this work by Roland Green, F.Z.S.

COLOUR-CHANGE IN PTARMIGAN.

The Ptarmigan (*Lagopus mutus*), first cousin of the Red Grouse, has three moults in the year. From April to July it has its finest plumage; the male is barred above with brown, grey and buff, mostly white below; the female is more tawny with black bars. From August to October the male is mostly grey above with fine wavy lines of black; the female shows more brown. In winter both sexes are white, except for black on the tail and quill shafts. In all phases the outer tail-feathers are black with white tips, and the quills are white with black shafts.

All this is what we call accommodation, and it reaches its finest development in birds.

There is seeing and seeing in many degrees on a long inclined plane. For the first use of the eye in the animal kingdom was simply to distinguish light and shade ; later on it was able to detect movements of surrounding objects ; later on it became an image-forming and colour-perceiving instrument—the chief gateway of knowledge. When light falls on our eye, passes through the window-pane and the watery fluid, through the lens and the vitreous humour, it falls on the retina. There it excites chemical changes, for instance in the pigment called visual purple ; it also excites electrical changes. Most important of all, it excites impulses in the rods and cones—impulses which travel by the optic nerve fibres to the brain, so that at length *we see*. Of course no one would call " seeing sparks " seeing, for on a dark night an unlighted lamp-post will suffice for that ! What happens in such a case is that the brain translates into terms of light every message that reaches it by the optic nerve, even when such message is the outcome, not of a light-ray, but of a wound or a blow. That all the messages brought by this one nerve are read in the same way is surely a very suggestive fact.

The Sense of Smell.

Smell means much for many animals, helping them to avoid enemies, find food, recognise kin, and discover mates. Occasionally it is of use in assisting an animal to find the way home. Its importance is increased by the fact that it pulls a trigger or gives the creature news from a distance—often much further than the eye can reach. Touch and pressure, sight and hearing, are physical senses ; but smell and taste are chemical. In taste there must be a watery solution of the palatable or non-palatable material so that it washes the taste-cells, which are usually, though not necessarily, in the mouth. In smell there is sense from a distance, for while the odoriferous particles must land on the olfactory cells, they may first have travelled a long way through the air.

Molecules spread far and wide from a volatile substance, which slowly decreases in weight. But all volatile substances are not odoriferous. The odoriferous particle must have a definite chemical basis—an organic nucleus to which are attached scent-bearing " osmophores " or groups of osmophores. If these groups of molecules called " osmophores " are removed, the odour disappears, but a great deal seems to depend on the precise way in which the osmophores are attached to the nucleus. For substances agreeing in their chemical architecture, but differing in the composition of nucleus and osmophores, may nevertheless have the same smell ! But these are deep waters. We must be clear, however, that just as there is a working classification of odours, such as Henning's fundamental six—" flowery," " fruity," and " foul," " spicy," " resinous," and " burnt "—so behind this lies a deeper and as yet incipient classification in terms of chemical architecture.

The remark often made that backboneless animals, such as insects, may detect many fragrances that are unperceived by man, is not convincingly confirmed by experiment. There is great difference between the smell patches in our nostril and the eight terminal joints on a bee's antenna, to which the olfactory sense seems to be restricted ; but there is a very remarkable resemblance between the bee's sense of smell and our own. The careful experiments of Frisch show that the bee recognises scents that we recognise, and fails with those to which we are insensitive. There is but one notable exception, and it is readily intelligible, that bees are peculiarly sensitive to their own odoriferous secretion. It might be objected that the dog contradicts what we have just said, for it picks up many a scent that is quite lost on us. But the probability is that the difference is rather in the degree than in the kind of sensibility. Different types of animals require different intensities of smell-stimulation. It must be admitted, also, that some animals and even human beings are quite unusually sensitive in regard to particular odours. Thus Fabre and others have shown that some male butterflies and moths will find the female from a considerable distance—even half a mile, and will find her in spite of such obstacles as a cloud of tobacco smoke. Very interesting is the fact that the male will sometimes seek out and discover the spot on which the female was previously resting—a fact sufficient to puncture the theory, attractive to some minds, that a particular kind of " ray " emanates from the female all forlorn.

All physiologists are agreed that the odoriferous molecules, if they are to pull the trigger, must come into very close quarters with the olfactory receptor cells, but what exactly happens is uncertain. It is likely enough that the details differ in different kinds of animals. When there is watery mucus bathing the olfactory cells, it may be that the odoriferous particles undergo some sort of external solution, as in the case of palatable particles beside the taste-cells. But many hold that the odoriferous molecules are absorbed by the olfactory cells, and undergo an internal change in the superficial zone of the living matter or protoplasm, where there is often an abundance of lipoid or fatty material. Henning, however, suggests that what takes place is a physical rather than a chemical process, what is called an adsorption not absorption, on the part of the receptor cells. On this view the intimate process would be somewhat like the colouring of animal fibres by aniline dyes. Everyone knows how certain odours, especially aromatic oils, will "cling" about the fibres of our clothes.

It is often said that thoroughgoing aquatic animals have no sense of smell, but as a general proposition this is not borne out by experiment. Observations on newts show that these animals nose about in a very characteristic way searching for pieces of dead earthworm hidden in the aquarium. It is easy to arrange matters so to exclude the assistance of sight; and there is no doubt that the newt finds its food by smell, even when it is totally immersed. It takes water in by the nostrils and expels it by the mouth, and goes on testing the water in this fashion until it has found the food. If there were any evidence that microscopic fragments of hidden earthworm were being drawn into the newt's mouth we might ask if the testing was not tasting, but there is no warrant for supposing that there were any earthworm particles in the case referred to, and there are also experimental ways of discriminating between taste and smell.

We are not, of course, pretending that it is always easy to distinguish between these two nearly related senses, especially when we take account of the fact that in many animals, such as our dogfish and the American catfish, there is a general chemical sense widely diffused over the skin. We illustrate this ourselves in a faint degree when vapour of ammonia makes our eyes water, quite apart from its smell. Many pleasant and unpleasant sensations that we refer to taste alone are, however, the joint effect of taste and smell, as we experience when we have a very heavy cold. For this smothers the olfactory cells, with the result that our pleasure in our food disappears though our taste-cells are quite unaffected.

In some reptiles and many mammals there is a paired organ (Jacobson's organ) typically communicating between the nasal chamber and the front of the mouth. It contains a little fluid and some sensory cells, and it may be that it serves as an auxiliary smelling organ. Bromann has made the interesting suggestion that the frequent shooting out and drawing in of the tongue in snakes may serve to bring the air before the tribunal of Jacobson's organ. He thinks that this may also be the meaning of the rhythmic twitching of the nostrils in some rodents.

In insects the usual seat of the olfactory receptors is on the feelers or antennæ. In crayfishes and lobsters and many other crustaceans the olfactory bristles are on the antennules, but they sometimes occur on certain mouth-parts. In ticks, the olfactory cells are localised towards the end of the first walking leg, which is used as a makeshift for the absent antennæ. Smell is very important to these ticks, for it enables them to detect suitable hosts to satisfy their thirst for blood.

We need not go further, for this is a good instance of the general proposition that a sense of smell is of wide occurrence in the animal kingdom. It has probably evolved from a general chemical sense diffusely distributed in the skin. The sense becomes specialised when it is of great importance for an animal to have its triggers pulled from a distance, whether in relation to enemies or friends, mates or kindred, food or a suitable host, or even in reference to the problem of getting home expeditiously. Many an animal has found it profitable to follow its nose.

Balancing Organs.

Fishes are often quick to perceive movements and disturbances in the water; some have smell and taste, others show an awareness of chemicals which do not stimulate either of these senses; but we must be very cautious in speaking of the

hearing of fishes. In a famous case where they used to come to be fed when the dinner-bell was rung at the edge of the pond, and where the conclusion was drawn that the signal was heard, more critical observation showed that a mistake had been made. When a sceptical zoologist took pains to approach the pond without being seen and without appreciable shaking of the ground, and then rang the bell behind a screen, not a single fish came to investigate. It seems safe to conclude that in this case the fishes had never heard the bell at all. Experiments made at Plymouth show that fishes learned to connect the sound of an electric bell in the water with the appearance of food, so we are not saying that fishes can never hear. Yet the bulk of the evidence goes to show that their developed ears must have some other function. Ears have they, but they hear not. Their ears have to do with balancing or equilibration.

The same is true of a large number of backboneless animals, especially of aquatic forms. They have highly developed ear-like organs, yet there is no evidence of the sense of hearing. Or if there is evidence of hearing, it often turns out to be independent of the ear-like organs. On the other hand, if the organs in question are injured or put out of gear, the animals cease to be able to keep their balance when swimming. In some cases they cannot even rest in the normal pose.

In many cases the balancing organ contains a hard concretionary body, sometimes like a minute pearl, which is supported on a little pillar, and is bathed by the water entering from without, or by a fluid filling a closed cavity. Abutting on or near the little body (the otolith or statolith) there are sensitive hairs arising from sensory nerve cells. When the animal is forced out of its normal position, the statolith's weight is felt on hairs and cells which are not normally affected; a message travels to the central nervous system; and there is an automatic or reflex response. By certain movements the creature adjusts its body so that equilibrium is secured. If it has been turned upside down there are righting movements, which are evoked as a reflex answer to the message sent from the disturbed statoliths.

In some animals the statolith is a single definite body, either wholly calcareous or partly calcareous and partly organic. In other cases, however, it takes the form of suspended particles or even crystals which jostle against the sensitive hairs when the fluid in the cavity oscillates. A third type is seen in many of the higher crustaceans, where the particles consist of finely powdered sand taken in from outside. In some cases the animal has been seen holding its forceps above the opening into its " ear " and bruising sand particles into fine dust, some of which finds its way in. When a crustacean moults, the lining of the so-called ear has to be relinquished, and when the animal is able to move about again one of the first things it does is to get a fresh supply of particles into its renewed " ear." This has opened the way for some pretty experiments which do not involve any operation. If a newly-moulted prawn is kept in a little aquarium where no particles are available, then its balancing sac must remain empty. This means that the animal cannot swim in a balanced fashion. Similarly, lobster larvæ reared in water containing no material usable for otoliths swim about anyhow, often upside down. In one experiment the newly moulted prawn was given some iron filings, and it utilised these as otolithic particles. In its subsequent career it used to be bamboozled by the approach of a magnet, for this, of course, affected the iron filings in the " ear," and the animal showed in its poses an interesting compromise between adjustment to gravity and adjustment to the magnetic attraction.

There is a small split-footed or Schizopod crustacean called Mysis which, like some of its relatives, has its " balancer " located at the end of the tail. If the organ be removed or badly injured the Mysis swims on its back, showing how much the equilibration has been disturbed. It is instructive to notice, however, that when it creeps on the floor of the pool, its movements are normal. This means that the sense of touch is compensating for the absence of the organ of equilibration. The normal statolith in this animal is interesting; it has an organic core, and outside that there are zones of calcium fluoride! As it sways about inside its little chamber it presses upon various sensitive hairs according to the position of the animal's body in the water. Automatic balancing results.

There are not many kinds of sounds that readily pass from the air into water, and, apart

from human contrivances, there are not many possibilities of sound-waves being produced in the water itself. Thus there is not much for aquatic animals to listen to, and most of their "ears" are not hearing ears but balancing organs. These are well seen in jellyfishes and swimming bells, and sea-gooseberries or Ctenophores; they are well developed in energetic animals like the higher crustaceans and the open-sea gastropods, known as sea-butterflies; they reach a high degree of complexity in the squids and other cuttlefishes. It must not be supposed, however, that equilibrating organs are confined to swimmers, for they are well developed in slow-going burrowers, like the fisherman's lobworm, in some tube-inhabiting animals, and in the sluggish bivalves. It is believed that they have always to do with the adjustment of the bodily pose. As far as result is concerned, their action in actively moving animals might be compared to that of gyroscope wheels in a monorail carriage, where a disturbance of the balance automatically evokes the movements that bring about its restoration. In a slow-going animal, as far as result is concerned, their action might perhaps be compared to the gimbal-arrangements for keeping a compass horizontal.

When we ascend the animal kingdom above the level of fishes we find the secondary function of the ear gaining on the primary. The ear becomes a hearing ear, as is also the case in some backboneless animals. Thus it has been proved that a male mosquito hears the female's hum. But it is in Vertebrates above fishes that the ear comes to its own as a receptor for sound-waves. Yet the balancing function does not disappear. Even in ourselves, in connection with the cavity of the ear, there are four "gravity-sacs" with sensitive cells that seem to respond to movements of an internal stone-like particle, and enable us, by the tidings sent to the brain, to keep our balance automatically. A great gift to be sure.

§ 6

SENSES OF PLANTS

It will be useful to make a short contrast between plants and animals as regards senses. Plants have no nervous system, and yet they are "irritable," as the physiologists say. They are sensitive to various outside influences, and they often answer back by some kind of movement. Therefore, we may speak of the senses of plants. There are, it is true, no well-defined sense-organs, like eyes or ears, in plants; but there are none in an animal like an earthworm, which is nevertheless sensitive to vibrations, light and shade, chemicals and odours. It must be remembered that there is a large class of animals, the Sponges, in which no one has been able to find any nerve-cells. Yet sponges are not insensitive; and we know of at least one British species that closes an exhalant aperture when provoked by an intrusive worm. In such a case the muscle-cells are themselves sensitive. But plants have no muscle-cells! Their movements are brought about by changes in the tension or turgidity of the

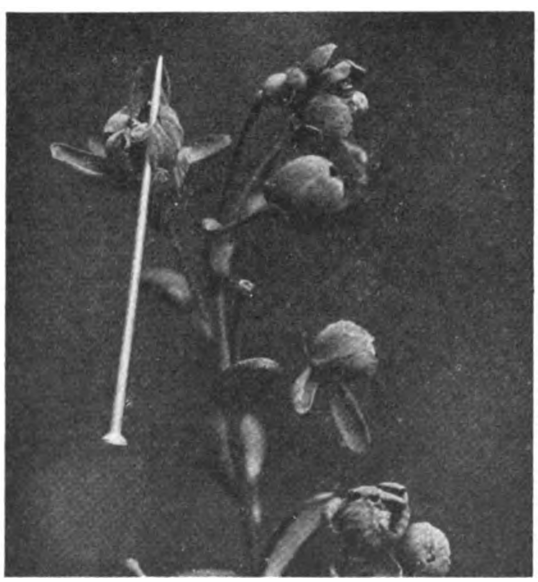


Photo: John J. Ward, F.E.S.

FLOWERS OF BARBERRY (Berberis).

The upper surface of the base of each stamen is very sensitive to touch. When it is stimulated by contact with a visiting insect's legs, the stamen moves sharply upwards and inwards, and dusts the insect with pollen. In the photograph the stimulated stamens are shown gripping a pin with which they were touched.

have grown towards a chink in the wall. It is plain that their constitution has been influenced by the scarcity of light—for the shoots are very flabby; it is also plain that they have grown towards the little light there was. Here we have to do with a diffuse irritability or sensitiveness and this is very common among plants. But when a leaf adjusts itself to a nicety so as to make the most of its light exposure, just as if it were an invalid adjusting his rotating summer-house, we have to distinguish the blade of the leaf as the main "receptor" of the stimulus and the stalk of the leaf as the main "effector." This

cells, or by unequal rates of growth in adjacent parts.

Thus we reach three interesting conclusions:

There may be sensitiveness without sense organs;

there may be sensitiveness without nerve-cells;

there may be movement without muscle-cells.

These conclusions are perhaps a little self-evident when we think of the many different kinds of single-celled organisms, that are irritable and motile, though they cannot have any organs. But the conclusions are worth stating in reference to ordinary many-celled creatures with bodies.

An unforgettable sight is sometimes seen in an almost dark, damp shed in a farmsteading where some potatoes have been left and forgotten. They have sprouted and sent out long, weak shoots, which

Photos: John J. Ward, F.E.S.

OPENING AND CLOSING OF CROCUS FLOWER.

The crocus flower closes at night and in dull weather; it opens in the morning and in sunshine. It seems to have been clearly proved for this plant that the opening and closing take place in response to changes of temperature. A closed crocus brought into a warm room soon opens. There is increased growing on the upper surface of the perianth of the flower; the parts become convex; the flower opens.

is the thin edge of division of labour; and is it not further than Sponges have got?

When unopened tulips or crocuses are brought into our sitting-room in the morning they soon expand, and this is very delightful. But when the room has become very comfortable, the flowers close up again, and this is rather disappointing; but can one avoid the conclusion that the plants are sensitive to temperature? As to this however, matter-of-fact physiological botanists will not allow us a long tether. The tulips and crocuses open because the upper side of the perianth (the outer flower-parts) grows more quickly than the lower side; warmth favouring chemical processes. But after a while the notably increased warmth reaches the other side of the perianth, and that grows rapidly in length, thereby closing the flower. If the room grew warmer still we suppose the tulips would open again, but we have never attained to that degree of comfort.

Somewhat subtler is the way in which the wood anemone, for instance, follows the sun with its beautiful blossom. Is it not, in a way, a vital thermometer? We take this case in particular because it has been proved experimentally that the movement of the wood-anemone flowers may take place in darkness if the temperature is periodically altered. In the familiar case of the sunflower, the influence of light counts as well as that of heat. There are a few plants that bend towards moonlight, that is to say, to reflected sunlight in the dark!

Many flowers like the daisy open and close with the growing and waning light of day, and many leaves have their diurnal and nocturnal poses. By the use of delicate instruments it has been possible to show that a tree may answer-back to the shade of a passing cloud. In some cases, especially in shade-plants, certain cells in the epidermis are fashioned like microscopic lenses, and Haverlandt has insisted on calling them ocelli or eye-spots. It seems probable, however, that their function is not perceptive, but to concentrate the scanty rays on the actively photo-synthetic green cells beneath the skin.

It has been noticed that the rootlets of higher plants will grow from a distance to a moist place in the soil, which is, of course, very profitable. The sensitive area is just

Photos: John J. Ward, F.E.S.

MOVEMENTS OF THE LEAVES OF THE "SENSITIVE PLANT" (*Mimosa pudica*).

The first figure shows the Sensitive Plant's fully expanded, beautiful, compound pinnate leaves. If these are gently touched the leaflets fold together, as seen in the second figure. The stimulus can travel from one part of the leaf to another, and from one entire leaf to another. Some botanists believe that a rapidly spreading hormone is concerned. The third figure shows the folded-up state. This is also the "sleeping" position assumed at dusk.

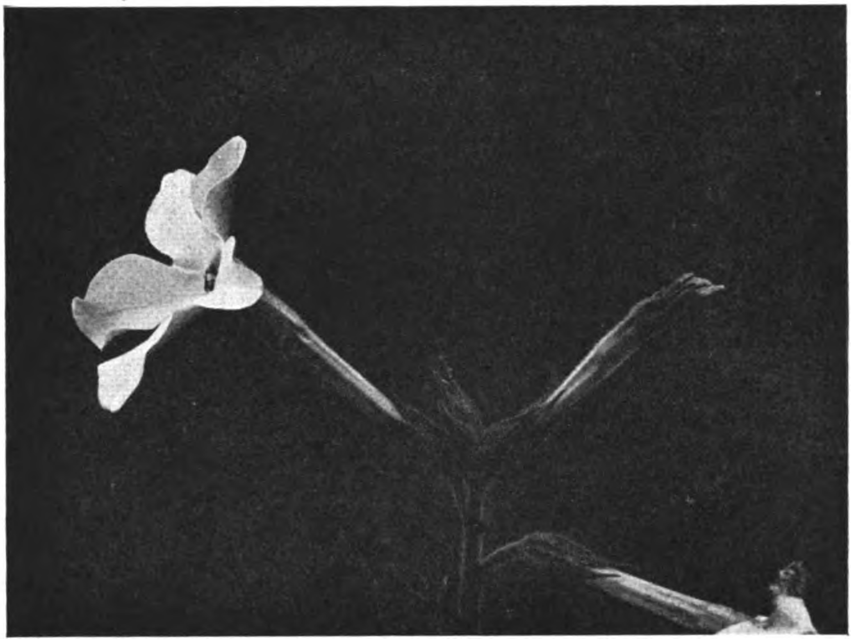


Photo: John J. Ward, F.E.S.

FLOWERS OF THE TOBACCO PLANT (Nicotiana).

The beautiful flowers of the Tobacco Plant open in the evening and close again after dawn. They are visited by long-tongued night-flying moths, which effect pollination. It is not as yet certain what brings about the opening and closing, but it is probably due to changes in the tenseness or turgidity of cells at strategic places; and this again may vary with the loss of fluid cell-sap from these cells, for this changes the pressure of the living matter on the cell-walls. Plant-movements depend on changes of turgidity or inequalities of growth.

at the tip of the rootlet and the direction of the movement is due to unequal rates of growth, as is usually the case with parts of plants that are still growing. Darwin showed that the tentacles of the sundew are exquisitely sensitive to very dilute solutions of certain chemicals, such as salts of ammonia. They move towards the centre of the leaf and secrete digestive juice. It has been shown that the sperm-cells of ferns and the like move towards malic acid, or swim from a weak solution to a stronger one, and it is this chemical sense that enables them to find the egg-cells.

When a growing stem of hay is " laid " by the wind and rain it is often able to right itself, and it does so by growing more on the turned-down side. It is sensitive to the altered conditions of gravity. The sensitive layer seems to be a starch sheath to the inner side of the rind. The cells of this zone contain large starch grains which have to change their position when the stem is no longer vertical. This change of position causes a change of pressure, and a stimulus to growth passes to the area of reaction where movement occurs. It is a difficult matter to understand, but in ordinary conditions a stem will grow up and a root will grow down if we invert them.

A sixth sense is touch, and many plants have it in a high degree. The tendril will respond to the light touch of a thread, the stamens of the rock-rose to an insect's legs, the mouth-like stigma of the musk to a pollen-grain, the leaves of the sensitive plant to a sudden jar. It is very interesting to find that there are, as in many animals, special " receptors " which convey the stimulus of touch inwards. On the tendrils of the cucumber there are cells with minute insinkings which agitate crystals of calcium oxalate, and these excite the living matter. On the movable stamens of the barberry there are touch-papillæ; on the leaf of Venus's Fly-Trap and on the sensitive plant there are touch-hairs. All this is very animal-like; there is receiving the message and passing it on, and there is answering back. But it must be noted again that plants have no nerve-cells or muscle-cells, and the rate at which messages travel in a plant is much slower than in an animal. It takes only a hundredth of a second for a message to travel from our finger tips to our brain, but the message sent in when a tendril is wounded travels at the rate of only half an inch in a second. If the tendril is merely touched, the message travels about one hundred and fiftieth of an inch in a second. We see then that, while plants have many senses, they are far from being " high-strung."

§ 7

FILTERS AND GLANDS

WE have seen that the chief products of the burning or oxidation process which goes on in all living cells are carbon dioxide and water, both of which find their way into the blood and escape from the blood through the surface of the lungs and the surface of the skin. But in addition to these completely burnt, fully oxidised compounds there remain certain unburnt " ashes " in the cell, which have to be got rid of. The most important of these are compounds of nitrogen—nitrogen which is one of the elements present in the proteins and therefore in all living matter. Nitrogen refuses to burn, either in the body or in the laboratory; it will not combine at all readily with oxygen, because the two elements are too much alike to unite firmly and easily.

The problem of getting rid of the nitrogenous " ashes " is one which confronts all living creatures. The leaf-like body of the liver-fluke is penetrated with the networks of two complex systems of canals, one bringing the food-materials from the mouth, and the other removing the nitrogenous waste products. But in the more highly organised backboned animals this double system of canals is unnecessary. The bringing of the food and of the oxygen, the removal of the carbon dioxide and the water and also of the nitrogenous ashes—all these problems of transport are solved by one highly developed system of communications: the blood.

Unfortunately it is not possible for the cell to burn all the carbon and hydrogen to carbon dioxide and water and to leave only the pure nitrogen gas as an unburnt waste product. This hundred-per-cent efficiency cannot be attained: the nitrogen has to be left in combination with some hydrogen and some carbon, which might otherwise be burnt away to water and carbon dioxide and yield energy. Nitrogen and hydrogen yield ammonia: and ammonia is formed by the cell as a waste product, and also in the splitting-up of proteins into amino-acids and other pieces during digestion; it is always present in the blood. But it is a dangerous compound and must not be allowed to accumulate; and consequently some carbon and some oxygen have to be sacrificed to change ammonia into a harmless compound urea; this transformation goes on busily in the liver. Urea has a special interest for the chemist, for it was the first natural organic compound to be artificially prepared, and till this was done, a hundred years ago, it was believed that the chemist could never imitate the chemistry of the living cell. It is the simplest and in mammals by far the most important of the nitrogenous waste products; next comes uric acid with a host of other elaborate compounds which are largely formed in the breaking-up of the peculiar proteins that occur in the nucleus of the cell.

All these are compounds much more complex than water and carbon dioxide, and though they dissolve in the blood and are swept away from the cells in the same way, they cannot be breathed out as vapours from the lungs or exuded through the skin. A special mechanism is required to remove the nitrogenous waste products from the blood, and that mechanism is supplied by the kidneys.

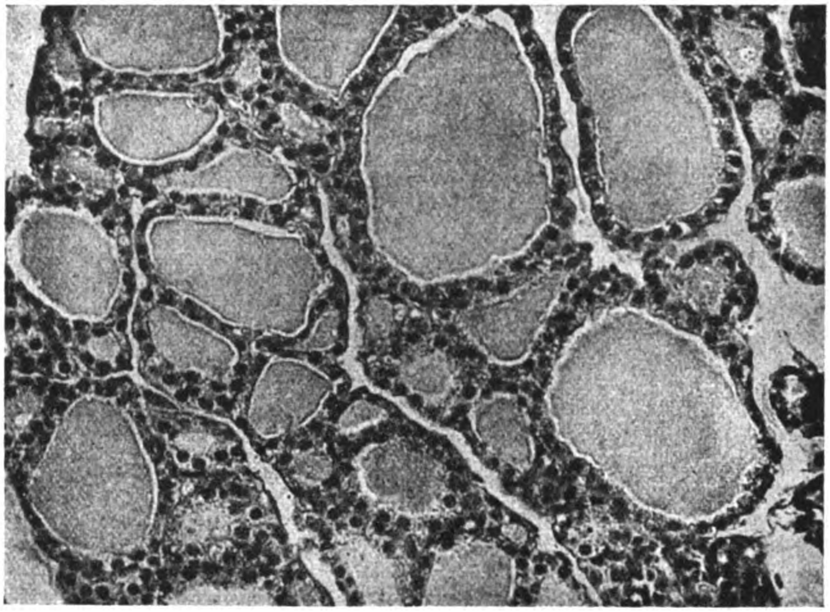
As well as forming a filter through which the nitrogenous waste can escape, the kidneys act as a safety-valve. There must always be a certain amount of water and of dissolved salts in the blood, but if the amount rises above the normal to a certain " threshold " value, definitely fixed for each substance, the excess " overflows " (to speak very metaphorically) through the kidneys. A good deal of water and of salts is got rid of in this way daily, for more is always being brought in by a normal diet. There is also a threshold value for sugar in the blood, but it is only when the body's power of storing sugar is lost through disease (diabetes) that this threshold is reached and sugar passes through the kidneys. The sum of the activities of the kidneys, the formation of the urine, which consists of the excess water and salts and all the nitrogenous waste products from the blood, with any other undesirable substance that may have passed through the kidneys, is called *excretion*; and though different animals solve

it in different ways, it is a process common to all.

Yet another function of the blood is to act as a carrier of chemical messengers. The carbon dioxide dissolved in the blood acts as a chemical messenger to the "respiratory centre" of the brain, and this chemical message causes the brain to send a nerve-message to the muscles which expand the lungs. But there are many more subtle and complex messengers than carbon dioxide.

After a meal, when digestion begins in the stomach, nerve-messages set the gland-cells of that organ to their task of pouring out digestive fluid into the alimentary canal. Such a process, when a cell acts as a chemical factory and gets rid of the substances it has produced, is called *secretion*, and the secretions of the stomach are various: there are digestive ferments, and there is hydrochloric acid. As the process goes on, and the half-digested food begins to travel further down to the intestine, the acid from the stomach has a peculiar effect on the cells lining the next tract of the alimentary canal: it causes them in turn to form a secretion but this is poured, not into the canal, but into the blood: it is *internal*. The blood carries this messenger-substance, which is called secretin, round the body and sooner or later to the great gland called the pancreas. Other tissues are unaffected, but the pancreas responds to the message by starting in its turn to form its own secretion, which consists mainly of digestive ferments, and is not internal but *external* like the stomach's, for it goes not to the blood but to the alimentary canal. This secretin, discovered by Professors Bayliss and Starling, is one of the best instances of a chemical messenger or "hormone."

Small glands situated close to the kidneys form a substance called ***adrenalin***, noteworthy as a chemical messenger whose chemical composition has been definitely ascertained. It is closely allied to one of the most important of the amino-acids, the building-stones of proteins. Small amounts of this substance are continually formed, but when the brain, under the influence of anger or fear, sends messages to the glands, they may pour out a much larger quantity of adrenalin into the blood, which carries it to all parts of the body. The effect of this is remarkable, though not unlike the effect produced by artificially stimulating the sympathetic nervous system (which is not under the control of the will). The blood-pressure rises, the heart beats fast, more sugar becomes available as a source of energy—in fact the whole body is suddenly more fit for vigorous action to cope with the emergency which caused the anger or fear. The hairs of the skin "stand up on end"—a reaction meaningless in ourselves, but how often have we not observed an angry



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SECTION OF THE THYROID GLAND OF A CAT.

(Magnified 200 diameters.)

The small dark circles are the nuclei of the epithelial cells, which secrete the thyroid hormone. The epithelial cells line numerous rounded or oblong vesicles, and these are usually filled with a peculiar viscid colloid of a protein nature. Into this colloid the hormone (thyroxin) passes, and thence by lymph-vessels into the general circulation. Thyroxin is one of the few hormones whose chemical composition is known.

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NETWORK OF LYMPH-VESSELS (FROM A RABBIT'S MIDRIFF).

a, the larger lymph-vessels, somewhat like veins, but with thinner walls and more numerous valves; they are lined with lanceolate cells, that is to say, like narrow pointed leaves; *b* and *c*, the smaller lymph-capillaries whose lining cells have wavy borders. The lymph-vessels spread through the tissues of the body and communicate eventually with the veins.

cat seeming to grow larger and more formidable, as the adrenalin which its rage has called out bears the "fiery cross" through its body, even to the minute muscles that erect the hairs.

The existence of these glands of internal secretion, also called "endocrine" or "ductless" glands, was recognised fifty years ago by the great physiologist Brown-Séquard. There are many still to be mentioned: the pituitary body at the base of the brain, the thyroid glands on each side of the wind-pipe, the small parathyroids beside them, probably also the pineal body on the roof of the brain (which is possibly the remains of a third, central eye, and is still very eye-like in some lizards) and the thymus, which in man is usually present only in childhood. By no means least in importance are the internal secretions which the sex glands pour into the blood.

All these glands form their various chemical messengers, probably continually in small amounts, as adrenalin is formed, but never in sudden rushes, as adrenalin may be. The chemical nature of the hormones is not known, except that adrenalin from the suprarenal bodies and thyroxin from the thyroid can be built up artificially. It is difficult, too, to make quite sure of the action of each one, since all are acting together, and probably there is a delicate balance between them. Moreover, it seems that the hormone of one gland acts upon another gland, causing it to be either more or less active. The skein is still much too tangled to be unravelled.

Children born with poorly-developed thyroid glands grow up as cretins, dwarfs with coarse skin and hair and low intelligence; the element iodine occurs in the thyroid gland and is of importance in the prevention of this disorder. Those whose thyroids are too large suffer from nervous irritability, are often thin, and their eyes protrude. Evidence of this kind, derived from the study of abnormal cases, and evidence derived from experiments on animals, tells us what we know of the whole system of ductless glands and the balance between them. They exert a penetrating influence on growth, not merely in size, but on the physiological changes of "growing up" and "growing old." They control fatness and thinness, the quality of skin

and hair. They influence the transport and use of the proteins and sugars as well as of the fats, and probably many of the scarcer compounds too, especially those of calcium. They may preserve the body to some extent from poisons of its own making.

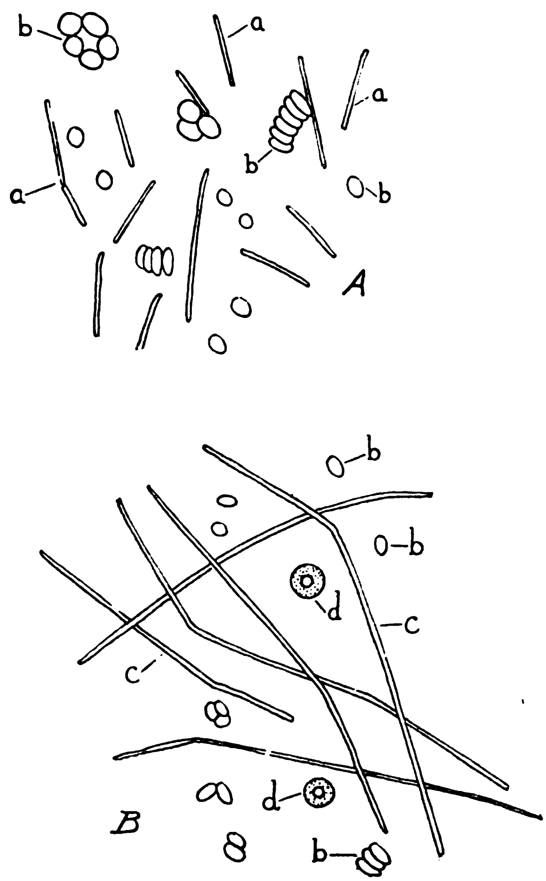
Internal Defences of the Living Creature.

This is a suitable place for thinking of some of the internal defences against the insidious attacks of poisons and parasites. Many a mineral has great capacity for endurance. It is not quickly weathered; it has a high degree of chemical inertia. But the slowly changing block of granite does not *do* anything, and thus it is not comparable in its endurance even to a midge, whose marvel is that it keeps agoing in spite of expending much energy for its size, and being the seat of intensely rapid, sometimes almost explosive, chemical changes. As a matter of fact, it does not keep up its midgy activity for very long; yet this short-lived insect is in its way true to the symbol of life—the Burning Bush—*aflame yet not consumed.*

Some progress is being made towards understanding how the living creature is able to repair or recuperate itself as quickly as it wastes or wears, and how it continues doing so for days, or months, for years or cycles of years. It is certain, for instance, that vital phenomena depend in great part on ferments, whose peculiarity it is that they can do a great deal of chemical work very rapidly without exhausting themselves. It is also certain that part of the virtue of protoplasm—the physical basis of life—lies in its being colloidal; a state of matter in which very minute particles are held in a fine state of dispersion in a fluid. They expose a large surface to the action of ferments and other reagents; they are in a very energetic state even when they pass from the " sol " state into a " gel "—from being like an emulsion to being like a jelly.

A third feature is that living creatures have a unique power of accumulating potential energy in the form of complex carbon-compounds; and this helps them to act very rapidly on the defensive. They have stores and reserves—in a word, capital. When we add to the ferments the colloidal properties, and the accumulation of energy, the more vital quality of being able, at many different levels, to enregister experience, so that living creatures give particular kinds of answers to different kinds of questions or stimuli, we are in a better position to inquire into their powers of persistence in a world which, though not always unfriendly, is certainly indifferent.

The relations between organism and environment are manifold. Thus the living creature may utilise its surroundings, as the green leaf uses a fraction of the sunlight that bathes it, or as we use the oxygen of the air in breathing. Or it may act more strenuously on its surroundings—shifting them about, boring into them, undermining them—even devouring them. This is the living creature's ***thrust.*** Or again, when surrounding conditions are difficult, the organism may evade them, as the migratory birds and the hibernating mammals evade the winter. Once more the living creature may



BACILLUS ANTHRACIS, THE MICROBE OF ANTHRAX OR WOOL-SORTER'S DISEASE. (After Koch.)

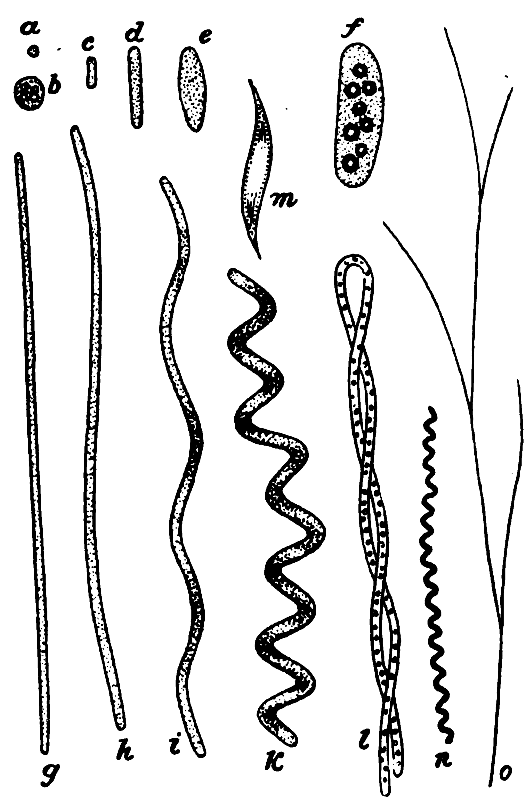
A. From a drop of blood taken from an infected rabbit. B. From the same, after three hours' cultivation in a drop of aqueous humour from the eye. *a*, the rod-like bacillus, in its non-motile phase; *b*, red-blood corpuscles; *c*, the bacillus grown into a filament, the Leptothrix phase; *d*, white-blood corpuscle or leucocyte.

individually develop, or racially evolve, some protection, it may be a thick skin or polished armour, from which the arrows of outrageous fortune glint off, doing no harm. This is the living creature's *parry*.

But there is an even more intimate kind of answer-back—what the living creature does when the enemy is not at the gates but within the walls, when there is fighting in the streets. Let us illustrate these *internal defences*. An animal is wounded and the blood begins to flow. If that continues long, the creature will die ; a fatal hæmorrhage, we say. But what often happens, if the wound be not too large or deep, is that the blood clots and the loss ceases. It is the commonest possible life-preserving reaction, but how difficult to explain ! The physiologists tell us that a complex substance called thrombin, which was not in the blood before, suddenly appears and changes the protein " sol " of the blood into a firm " gel " of fibrin, an organic sticking-plaster over the cut !

Of great importance are the reactions which save many organisms from the dangers of extreme heat and cold. In lower forms of life there is often a relapse into deep inactivity, which is self-preservative ; the fire of life burns very low, one can hardly say more than that it is " not out." The vital fermentations cease for a time, and the protoplasmic molecules are saved from disintegration by lying low. A goat-moth caterpillar may be so gripped by the cold that it breaks across in our fingers, yet the broken off anterior end will move about again when slowly warmed. In birds and mammals, which are known to be " warm-blooded," there are delicate adjustments which keep a balance between the production and the loss of body heat ; and we do not know which most to admire—the ordinary heat-regulating arrangements which secure for birds and ordinary mammals a practically constant temperature, day and night, year in and year out, or the exceptional conditions illustrated by the imperfectly warm-blooded winter-sleepers. In most cases it may be said that the defences against extreme variations of temperature depend fundamentally on the protoplasmic fermentations.

One often sees a goat or some other animal eating a poisonous plant, and though fatal mistakes are sometimes made, the big fact is that living creatures can become accustomed to almost anything. We see the snail enjoying a poisonous fungus, and while from the horticultural point of view we hope the meal may be fatal, we know that nothing happens. There are people in the Tyrol who are quite healthy, though they use arsenical preparations that would kill any of us the very first time. The Oriental who visited De Quincey and put into his mouth a piece of poison that made even the Opium-eater stare, was never found dead ! The word poison is relative ; what is one organism's poison is another's food. It is probable that the goat or the donkey becomes like Mithridates, King of Pontus, who was so habituated to poisons from his youth up that he became immune to them all ! In any case, the living creature has



VARIOUS FORMS OF BACTERIA.

a, minute sphere or micrococcus ; *b*, larger sphere or macrococcus ; *c*, short rodlet or bacillus ; *d*, longer bacillus ; *e*, somewhat oval Clostridium form ; *f*, very large bacillus with sulphur granules, the so-called peach-blossom bacillus ; *g*, thread-like Leptothrix form ; *h* and *i*, a slightly and a more markedly curved vibrio form ; *k*, a spirally twisted spirillum form ; *l*, a spirillum folded on itself ; *m*, a very short twisted form, referable to the spirillum type ; *n*, a close-set spiral form ; *o*, a branched bacterium, the Cladothrix type. All except *o* are magnified more than a thousand times.

astonishing powers of adjusting itself to and learning to counteract frequently recurrent poisons.

The severest test to which an organism can be put is a serious infection, for that means that living enemies have gained entrance into the fortress. Sometimes the activity of the invaders is strictly confined to one place, and they dissolve away cellular material at some particular spot till a breakage (or lesion) results ; sometimes they produce a secretion which has a poisoning effect far and wide throughout the body ; sometimes there is both a local and a general disturbance. What the invaders bring about is, of course, very subtle, but it means fundamentally that the colloidal balance in the living units of the body is disturbed, it may be fatally, by what the intruders produce.

The first defensive reaction of the invaded animal is the production of an anti-poison or anti-toxin which counteracts the poisonous influence of the microbes. Roux and Yersin discovered the toxins or poisons that are produced by microbes ; Behring and Kitasato proved that counteractives or anti-toxins were also formed ; Roux and Martin showed how anti-toxins produced in one organism may be introduced into another that has been infected by microbes, and may not be able to produce counter-activities of its own quickly enough or abundantly enough to secure the defeat of the invaders. It should be noted that anti-toxins have not as yet been isolated, and it is possible that they are not definite chemical substances. They may be properties of the colloidal balance or equilibrium. But there is no doubt as to their efficacy.

The second great defence is by means of phagocytes—a discovery mainly due to the genius of Metchnikoff. From sponges to man, with few exceptions, the organism has a body-guard of mobile amœboid cells which are able to engulf and digest intruding microbes. In backboned animals the phagocytes are specialised white-blood corpuscles, slightly different from their neighbours. In some cases it seems that the invaders cannot be engulfed and digested unless they have been previously weakened by an " opsonin " in the blood. This " opsonin " may be the anti-toxin already referred to.

The defensive values of anti-toxins and phagocytes are generally recognised, but the same cannot be said of Dr. D'Herelle's interesting theory of " Bacteriophages." These are believed to be ultra-microscopic microbes, normally present in the food-canal, the deadly enemies of intrusive disease-causing bacteria. They are supposed to form secretions of great potency which educate the phagocytes and dissolve the bacteria. According to Dr. D'Herelle, they are our unrecognised guests or partners that help us towards immunity, though by no virtue of our own. But this theory of friendly and helpful partner-microbes that rise up against unfriendly and intruding disease-microbes is still on its trial.

§ 8

COLOUR-CHANGE

AS an interesting illustration of physiological inquiry, let us consider the changes of colour that contribute much to the beauty of living Nature and often, also, to the welfare of animals.

There are several different kinds of colour-change among living creatures. In the spring the larch trees put on a beautiful veil of green, and that is due to the multiplication of chlorophyll corpuscles in the young leaves. In autumn we see " the flowers of the forest " in the withered leaves of mountain ash, wild cherry, sycamore and the like—a transfiguration mainly due to the breaking down of the chlorophyll and to the appearance of a special pigment called anthocyan. Much the same occurs when the green apples become gradually rosy-cheeked. The colour of a flower is sometimes changed by a chemical that seeps into its roots from the soil. Or a something new in colour may be due to some shuffling of the hereditary cards, such as occurs in animals when a white blackbird emerges.

If one explores the Cairngorm mountains in

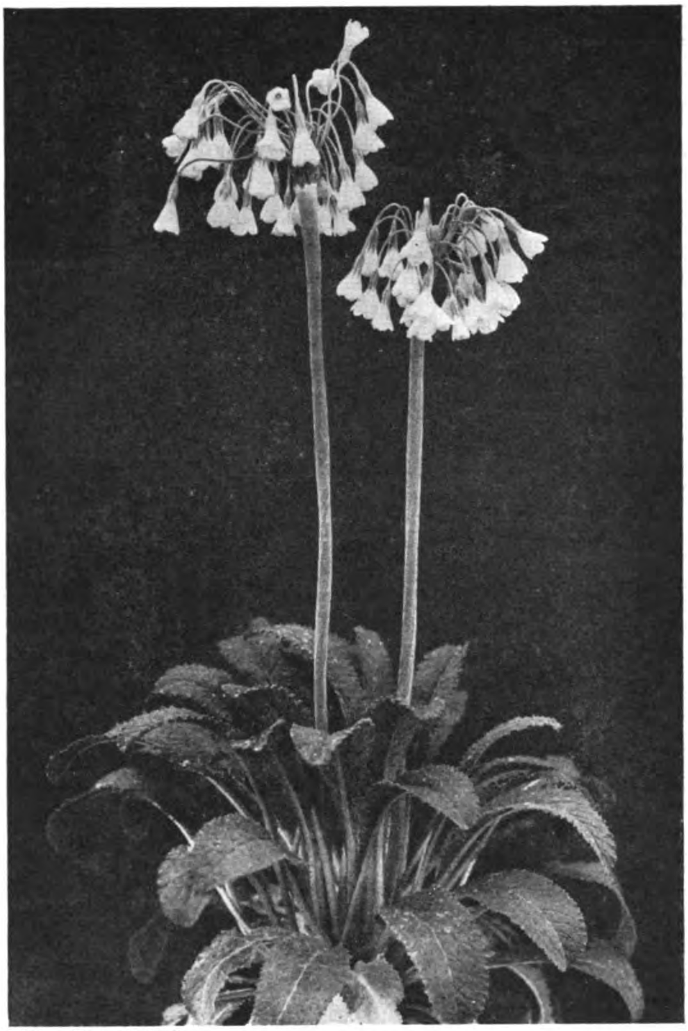


Photo: Reginald Malby.

CHINESE PRIMROSE (*Primula sinensis*).

Primroses occur in two forms—(*a*) long-styled, with the stigma at the mouth of the corolla tube and the stamens half-way up; and (*b*) short-styled, with the stigma half-way up the tube and the anthers at the mouth. When bees and butterflies visit the flowers they tend to carry the pollen from the high stamens to the long style or from the half-way stamens to the short style; and the interesting thing is that these crossings yield most seed. This species is known in cultivation as red-flowered and white-flowered forms, this depending on temperature and moisture.

spring, one sees queer betwixt-and-between stages of the ptarmigan—colour-phases intermediate between the almost snow-white plumage of winter and the brown, grey and tawny summer suit. The new-grown feathers contain an abundance of brownish pigment, which takes the place of the gas-bubbles that caused the winter-whiteness. At the same season on the same mountains there are many intermediate phases of the Variable or Blue Hare; the white winter pelage is being replaced by complex brown. The same is true of the white ermine, which changes in spring into a brown stoat.

The converse winter change to whiteness means in the main that the hairs of the new suit have little or no pigment and much in the way of gas-vacuoles, which form many little light-reflecting mirrors, but there are cases where an individual hair changes to white. This may be effected by the entire removal of the pigment through the agency of wandering amœboid cells or phagocytes, and the replacement of the pigment by gas-bubbles. Or, more simply, it may be that abundant gas-vacuoles mask the pigment. There is no white pigment among animals, though white *colour* is common. For we must be careful to distinguish between pigmentation and colouration.

Long exposure to the sun increases the deposition of darkish melanin pigment in the human skin, and we say that the explorer is tanned by the Tropics. The occurrence of freckles is, we believe, of the same nature. On the other hand, good news changes the colour of the face, and the physiology of this flushing is a quickened circulation and a temporary enlargement of the superficial capillaries. But the pallor of righteous anger means that the emotion has, through the sympathetic nervous system, affected the suprarenal glands, which secrete adrenalin more copiously. The adrenalin, passing into the blood, has many effects, including a lessened blood supply to the peripheral regions and the consequent paleness. How subtle colour-change may be!

The colour of a canary can be changed to some extent by altering the character of its food; and the colour of some caterpillars is also due to the food-plant on which they feed. Whether a Chinese primrose has red or white flowers depends mainly on the temperature of the greenhouse. These must serve as samples of the variety of colour-change in living creatures for we wish to clear the ground for a short

discussion of a recent advance that has been made in our understanding of yet another type—the quick colour-response of animals like chamæleons, frogs and flat-fish. The advance is due to many investigators, notably to Dr. L. T. Hogben (see his "Pigmentary Effector System," 1924).

When a frog, normally greenish in hue, is placed in a dark moist box in a cold room it becomes dusky in a few hours, and black in a couple of days. But if it is put in a whitened dry box in a brightly lighted and warmish room it soon puts on a lemon colour. How does this come about? The colour-change is due to the expansion or contraction of the living matter of dark pigment-cells (melanophores) in the frog's skin. There are also cells with yellow pigment (xanthophores), and these show up prominently when the black cells have contracted to microscopic pin-points. It is possible that a dark pigment-cell, which is much branched, may contract as a whole in an amœboid fashion; but it seems more likely that in the frog and other vertebrates there is simply a contraction of the pigmented living matter within the irregular interior of the cell. This is certainly the case in crustaceans like the Æsop prawn. But it makes little difference whether it is the whole cell that contracts, or only the protoplasm within the cell.

What is true for the frog is true with slight changes for the chamæleon and for flat-fishes like the plaice; and until recently the general account of what happens was something like this. Outside conditions, such as those of

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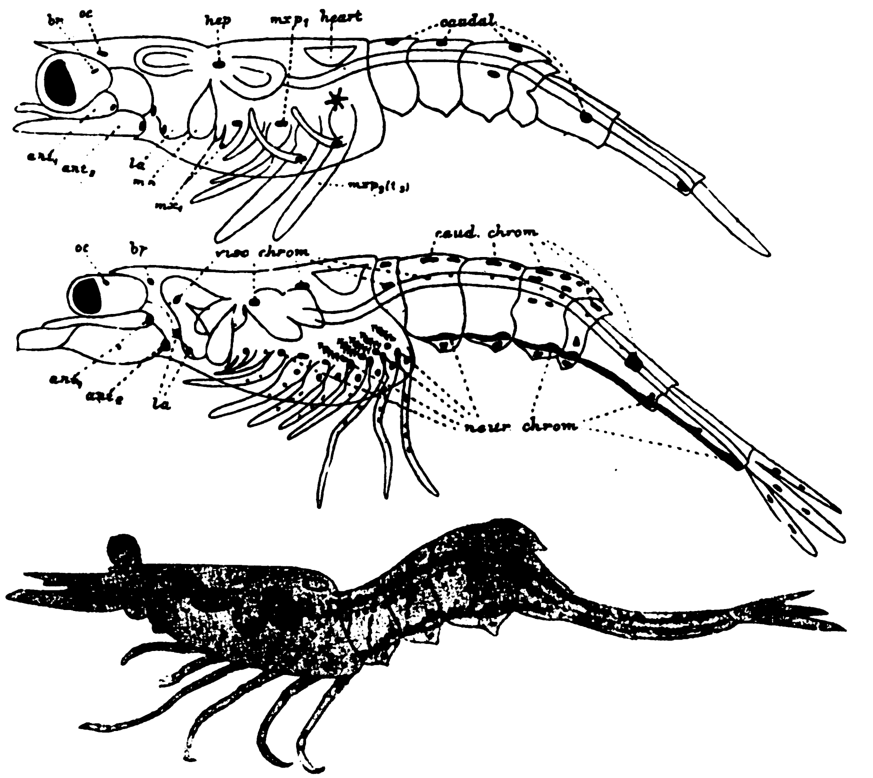
SKATES AND DOGFISH.

Colour-change is illustrated very markedly by the bony flat-fishes, such as plaice and flounder, but not by the entirely different gristly flat-fishes, the skates and rays. A skate is flattened from above downwards; it rests and swims on its under or ventral surface, which has little pigment or none. A bony flat-fish is flattened from side to side, and the down-turned side is without pigment, but with silvery spangles of guanin. Plaice, soles, lemon soles, dabs, flounders, witches, halibuts, and the long rough dab swim on their left side (the heavier); turbot, brill, and megrims on their right side, which happens to be the heavier.



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COLOUR-CHANGE IN THE ÆSOP PRAWN (Hippolyte).

By day the adult Æsop prawns are reddish-brown or bright green according to the colour of the seaweed to which they are clinging. A green one placed on brown seaweed becomes gradually brown, and vice versa. But the change may take a week. Whatever the day colour may be, the prawn changes about nightfall to a beautiful transparent blue or greenish-blue. The black dots are little groups of pigment-cells or chromatophores, *caudal* on the tail, *neural* towards the ventral surface, and *visceral* midway up. The chromatophores contain yellow or red or blue pigment. The uppermost figure is the free-swimming larva; the middle figure the adolescent stage, when it settles on its weed; the lowest figure represents one of the many coloured varieties. Particular chromatophores (*chrom*) are named—ant_1 on the little feelers or antennules; ant_2 on the longer feelers or antennæ; *oc*, on the eye-stalk; *br*, near the brain; *hep*, near the liver; *la*, about the lips; *mn*, the mandible; *mxp*, a maxillapede; the heart is also shown.

illumination, affect the eye or some other receiving station in the animal. Thus a *blind* plaice does not take on the pattern of its surroundings. In ordinary cases of colour-change in fishes, the news passes from the eye to the brain, whence orders are issued, by means of the sympathetic nervous system, commanding the pigment-cells (or chromatophores) in the skin to contract or expand. In short, the co-ordination between the receptors (receiving the news) and the effectors (giving effect to the orders) was interpreted as a *nervous* linkage. And this is in certain cases among fishes an accurate account of what occurs. It may be, however, that the nervous control is not the only control in fishes.

The normal colouring of a frog is the balanced result of normal conditions of moisture, temperature, oxygen-supply, and illumination, and it fluctuates with changes in these environmental factors. According to the brilliant researches of Hogben and Winton the regulator of the changes is the hormone produced by the frog's or other amphibian's pituitary body. This passes into the circulation and induces contraction of the dark pigment-cells situated in the outer and under skin. If the amount of the pituitary hormone in the blood circulation changes, then the colour of the skin must also change. Without the hormone the animals are permanently pale! This is an exceedingly important conclusion, especially when we note that there is no proof as yet of nerves passing to the dark pigment-cells or melanophores of amphibians. The advance here is the replacement of an unverified hypothesis of nervous control by an experimentally well-grounded theory of hormonic control. Of course the deep-seated ductless glands just referred to must first be affected through the nervous system, and that in turn must get its stimulus from superficial receiving stations (or receptors), not necessarily the eye.

In reptiles, such as the chamæleon and the so-called "horned toad," the pigmentation is more complicated than in amphibians. The skin shows a superficial layer of yellow or iridescent "interference" cells, and a deeper layer of black cells with branching processes ascending into the outer layer. Most of the

colour-change is due to up-and-down movements of pigment granules in the dark cells. Bright light and low temperature promote expansion of the melanophores, and this means a darkening of the skin. Darkness and warmth lead to a contraction of the melanophores and this spells pallor. There is some evidence that outside conditions may affect the reptile's skin directly, but in the main the colour-change, notably the pallor which follows irritation, is evoked by the adrenalin hormone, which is secreted by the suprarenal bodies. How far the colour may also be affected through the eyes remains uncertain.

What is the state of affairs in fishes, where the colour-response to a changed background is sometimes almost instantaneous? How quickly a flat-fish can make itself invisible! The most important elements here are the black pigment-cells in the under skin (or dermis), and the control is due to branches of nerve-cells belonging to the sympathetic system, which sometimes almost envelop the chromatophore. It seems, then, that the predominant factor in regulating colour-changes in response to outside influences is by pituitary secretion in amphibians, by adrenal activity in reptiles and by direct nervous control in fishes. But Dr. Hogben is careful to add that these three arrangements may perhaps co-operate in different measure in all three classes.

In crustaceans, like shrimps and prawns, there is often a beautiful colour-change, and there is also a rhythm between transparency at night and expansion of the pigment cells by day. The chromatophores are usually multicellular or multinuclear structures, and in many cases they contain more than one pigment with differences in the rate and extent of their diffusion. It has been shown that the response to darkness and light is a direct reaction of the chromatophores, independent of the eyes. But there is also a subtle reaction to the *colour* of the background, and this depends on the receipt of light by the eyes, the essential point being not the intensity of the illumination, but the direction of the incident rays.

All this variety is intricate and in some degree puzzling, but it is profitable to be patient with it, for it shows how subtle vital changes are, and also how the same result may be reached in different ways in different animals.

In cuttle-fishes, which are of course molluscs, the arrangements are again different. The chromatophores are little multicellular sacs, often visible to the naked eye, and remarkable in being surrounded by radiating muscle-fibres, which are well-innervated. As these fibres contract or relax, the size of the chromatophore or the dispersion of its pigment or pigments is altered. The play of colour on the octopus is singularly beautiful. There is some evidence that the colour-response in this case is under the control of the nervous system, but there is also strong evidence that the chromatophores respond directly to external changes. How varied, at present, are the answers to the question: How does an animal change its colour in relation to its environment?

The colour-change may be of value in making the animal inconspicuous; it may also in some cases add to the aggressive appearance. But it is important to keep in mind the possibility that in some cases it may not be of direct use at all, but may be, like blushing or turning pale, merely an expression of internal excitement.

§ 9

INCLINED PLANE OF BEHAVIOUR

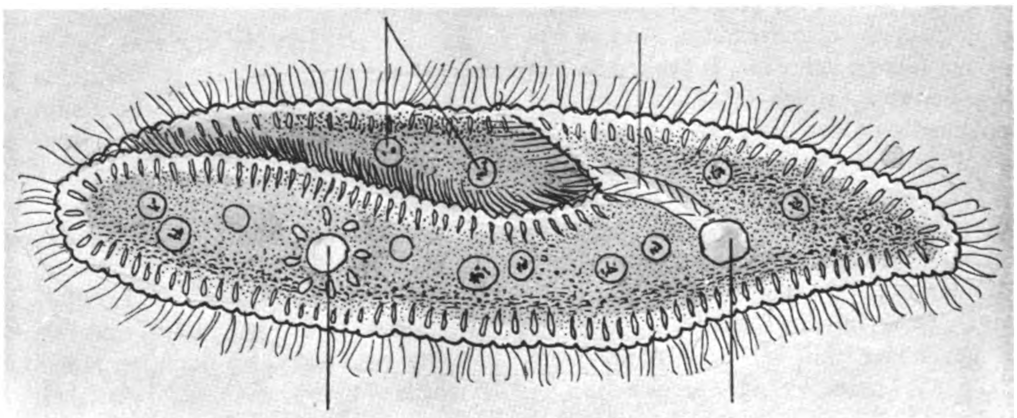
A GREAT many of the chapters of this book have been devoted to the *doings* of animals, while this more difficult physiological chapter has dealt with what lies behind external activities, namely, the internal functions of the body, such as muscle contraction, breathing, digestion, and the circulation of the blood. It is obvious that these are not ends in themselves; their significance is that they enable animals to be doers and to enjoy their life.

Therefore it is fitting that we conclude by drawing the threads together, for the whole of behaviour is like a web with a pattern that becomes more and more complex. Let us then

revise our previous studies of animal behaviour by beginning with the simplest and working upwards.

1. A microscopic Infusorian in the shore-pool answers-back to light, warmth, increasing saltness, floating food-particles and other outside influences. It has a number of reactions to changes in its surroundings.

2. Very common almost everywhere in fresh water is the Slipper Animalcule (Paramecium), an elongated oval about one hundredth of an inch long, covered with rows of lashes or cilia, which bend and straighten continually and harmoniously, so that they drive the little animal at a great pace through the water. When the Slipper Animalcule meets some obstacle or something obnoxious, it reverses its cilia, retreats to a short distance, twists a little on its own axis, feels with its front end, and goes off again, full steam ahead, in a slightly altered direction. It may miss the obstacle or obnoxious influence this time; if not it repeats the performance. In this case there is one particular answer to almost every question. The Slipper Animalcule has an engrained capacity for answering back in a particular way.



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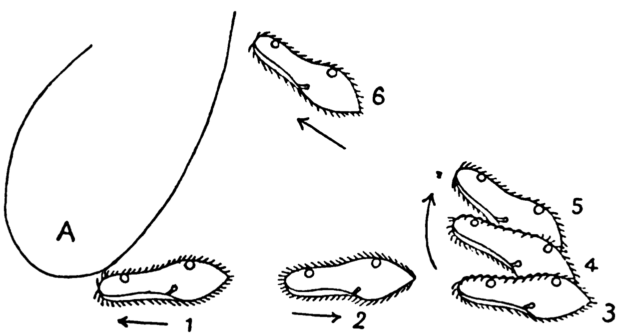
THE COMMON SLIPPER ANIMALCULE (*Paramecium caudatum*).

This Infusorian, common in freshwater everywhere, is about a hundreth of an inch in length. It is covered with lashing cilia. On the ventral surface (here upturned) there is a "mouth opening," leading by a so-called "gullet" (Gul) into the protoplasm. There is a bubble of water (F. vac., food vacuole) round each particle of food taken in. There are two pulsating contractile vacuoles (C. vac.), which get rid of fluid waste. At the base of the cilia there are protrusible mooring threads (trichocyots).



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BEHAVIOUR OF PARAMECIUM. (After Jennings.)

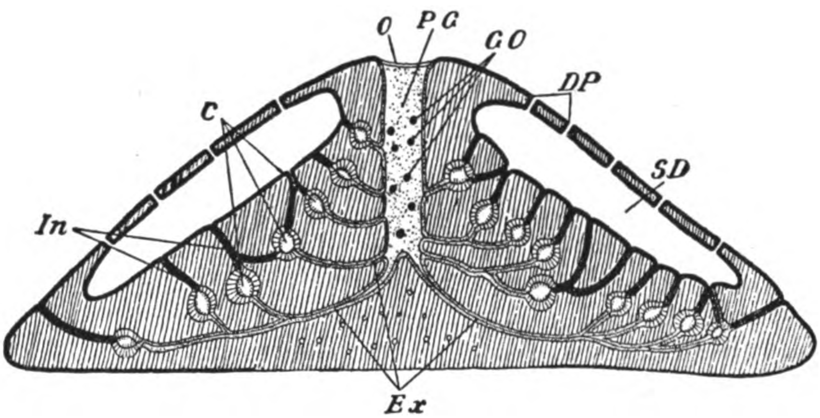
When the Slipper Animalcule (1) draws near some obnoxious influence (A), it reverses its cilia (2). Having retreated a short distance (3) it twists on its own axis (4, 5), testing the water with its anterior blunter end. It flexes its cilia in the normal way, towards the sharper posterior end, and shoots ahead (6) in a new direction. The chances are that it thus avoids the obnoxious influence; not, it repeats the process.

3. There is a green freshwater Infusorian called Stentor, with a trumpet-shaped cell fixed in a protective sheath. If a shower of microscopic dust be made to fall on it, the answer may be (*a*) bending to one side, or (*b*) reversing the action of the cilia around the mouth so that the particles are driven off, or (*c*) contracting into its sheath and waiting a little. If none of these reactions proves of any avail, the Stentor may (*d*) loosen itself and swim away to another place. In this case there is "trial and error" behaviour. The little creature gives one answer after another, until it finds the right one.

4. On the surface of a living sponge in a shore-pool one sees large openings like the craters of volcanoes, and if one watches carefully one may see by the motion of particles that water passes out by these " oscula." It passes in by minute pin-prick openings all over the surface of the sponge. Now it sometimes happens that an inquisitive intruder, such as a sea-worm, pushes its head into an osculum, whereupon, in certain cases, e.g., the British sponge called Pachymatisma, the crater-like opening shuts. For round the circular opening there is a ring of spindle-shaped, slowly contracting muscle-cells (of the type known as smooth or unstriped, such as we have on the wall of the food-canal), and these close the opening. This is particularly interesting, for there are no nerve-cells in sponges. The muscle-cells are directly stimulated to contract, whereas in all animals above sponges the muscle-cells are stimulated not directly, but through the nerve-cells which have received the message from the outer world. This, then, is a piece of behaviour simpler than the simplest " reflex action."

5. When a small worm touches the tentacles of a sea-anemone there is a discharge of stinging lassoes, and the benumbed grappled victim is transferred to the mouth. This is a very simple action: sensory skin-cells, not specialised however, pass on a message to nerve-cells or ganglion cells forming a deeper network, and thence comes the stimulus to the muscle-cells inciting them to contract. In some parts of an earthworm a sensory nerve-cell in the skin receives a message and passes it on to a motor nerve-cell in the nerve-cord, whence commands go to a muscle. This is the simplest kind of reflex action. But in many cases in the earthworm the chain has three links: the sensory nerve-cells (scouts), the associative or communicating nerve-cells (General Headquarters), and the motor nerve-cells (executive officers). In all ordinary reflex actions there are these three links, but in most cases each operation concerns *several* scout-cells, *several* G.H.Q. cells, *several* Motor or Executive cells, and *several* muscle-cells. Moreover, many reflex actions are not over and done with in one operation, as when we jerk our finger back from a hot iron; there is often a chain of actions as when a young mammal sucks.

6. Animals are prompted by constitutional " urges " or " drives," appetites and appetencies, especially hunger and love in the widest sense, which demand satisfaction. They are the fundamental motives.



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DIAGRAMMATIC VERTICAL SECTION OF A FRESH-WATER SPONGE (Spongilla), SHOWING THE ARRANGEMENT OF THE CANAL SYSTEM.

The water enters by minute pinprick pores on the surface of the sponge (DP, dermal pores); it passes into what may be called porch spaces (SD, subdermal cavities); it is drawn on via inhalant canals (In) into the ciliated chambers (C) which are lined by collared flagellate cells. Thence the water, robbed of some of its oxygen and food-particles, passes into the exhalant canals (Ex), which open (GO) into an exit passage (PG, the paragastric cavity). Thence the water passes out by the visible exhalant opening or osculum (O). The ingoing and outgoing currents are kept up by the ceaseless wafting of the collared flagellate cells, which are technically called choanocytes.

7. When a moth is flying past the lighted candle one eye is more illumined than the other. This disturbs the balance of activities in the nervous and muscular elements on the two sides of the body, and there is an automatic tendency to adjust the body so that equilibrium is restored. To this unconscious end both eyes must be equally stimulated, and this usually means that the moth flies into the flame. This kind of engrained constitutional obligation to secure equilibirum is called a tropism, and it is illustrated by many animals. The young eel making its way upstream in obedience to an inborn impulse, tends automatically to have both sides of the body equally pressed upon by the current.

If one side is receiving much more pressure than the other there is an automatic muscular adjustment which restores equilibrium; and this tends towards persistent upstream swimming.

8. We have seen that a newly hatched Loggerhead Turtle makes for the sea and usually persists in the right direction in spite of obstacles. Its constitutional make-up leads it to move in the direction of the more open horizon, which usually means the sea. What pulls the trigger of an inborn pre-arrangement is the difference between an open horizon and a much interrupted one. This seems rather different from the moth-and-the-candle obligation.

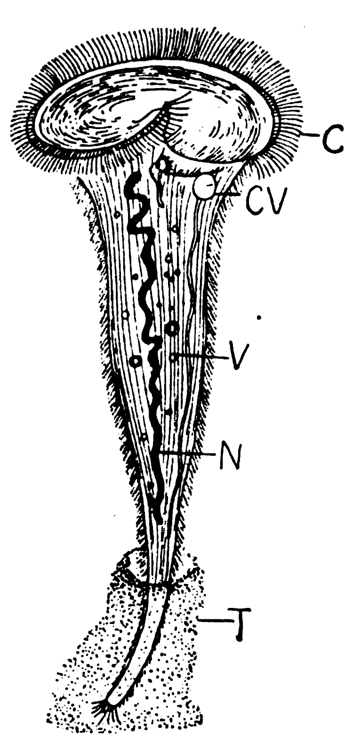
9. When there is a definite chain of reflex actions bound into an effective piece of behaviour, each link supplying the cue to the next link, we speak of instinctive behaviour. It does not require to be learned, though it may improve a little by practice. It depends on inborn pre-arrangements of certain nerve-cells and certain muscle-cells; but there are good reasons for believing that it has also a psychical side that counts. It is suffused with awareness and backed by endeavour.

Soon after its escape from its chrysalis the female Yucca moth makes for the Yucca flower as if it had been doing it all its life. It collects pollen and the front of its head is laden with the golden dust. It visits another Yucca flower and lays its fertilised eggs in the seed-box, but before doing this it is bound to land some of its store of pollen on the stigma of the second flower. There is a chain of events and the moth goes through the routine without error, being, in fact, "to the manner born."

10. On another tack, however, there is experimental behaviour, displaying some novel initiative. The animal, confronted with a new situation, tries its repertory of ingrained reactions and one of these may serve. But it may also hit off something new—an individual expedient. Thus some starfishes attack small sea-urchins and disarm them, and we cannot call this intelligent, for the starfish has no brains at all. Especially in new situations many an animal tries and tries again, but those whose behaviour is very thoroughly stereotyped along instinctive lines have usually less power of experiment than those less perfectly equipped.

11. Intelligent behaviour demands, as we have seen, some judgment, some understanding of the situation, as when an ape uses a lever, or an elephant selects out of several twigs the one best suited for removing a leech from its body.

12. When the tide is low, hermit-crabs move away from the light; when the tide is high they persistently seek the light. This periodic rhythm is engrained in the constitution of the individual and it persists for three weeks in a tideless aquarium. The green worm Convoluta, common on the flat beach at Roscoff, comes up out of the sand when the tide is out, and retreats when the splash of the flowing tide is near. This engrained periodic rhythm lasts for a week or so in a tideless aquarium. Some animals, like some men, become restless and miserable when the usual periodicity of their meals is disturbed, and, perhaps, the same kind of rhythm is seen in the restlessness of some migratory birds when the time for their autumnal flight comes round.



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STENTOR, A TRUMPET-SHAPED CILIATED INFUSORIAN.

The species *Stentor polymorphus* has a green colour, due to the presence of partner Algæ; the species *Stentor cœruleus* has a blue pigment of its own. T, a tube or sheath, formed when the Stentor is attached by its tapering hind-end; N, the peculiarly long nucleus; V, a food-vacuole; CV, a contractile vacuole; C, cilia in a spiral around the mouth, which lies to one side.

13. It is not difficult to get some of the cleverer animals to learn to associate a particular sound or sight with a particular experience. A cat or a dog learns that a particular sound means a particular experience, and a dog's mouth may water when the signal of its food is given, though no food is there. In the childhood of many wild animals there seems to be a

period during which associations are established in addition to those with which they are equipped at birth. The young partridge squats when it hears the parental danger-call, that is instinctive. But we know that a dog may *learn* to link together a particular sound with a particular action, and we have reason for believing that young otters, young foxes, young stoats, and the like *learn* (partly under parental instruction) to associate certain sounds in the country with particular kinds of action. Even fishes, which have poor brains, learn to associate a man's presence by the side of the pond with the possibility of a meal.

14. It is useful to keep the word habit for chains of actions that become easy in the course of frequent repetition, so that they cease to require attention or control. Linkages between certain nerve-cells and certain muscle-cells that are repeated over and over again in the individual experience become easy; what are called "paths of low resistance" are formed in the central nervous system; the oftener the message travels along the chain, the quicker and surer its transit becomes. The path becomes well trodden. We are familiar with this in writing, in bicycling, in playing the piano. What originally required attention and control becomes so easy that we speak of it as automatic.

There are simple one-act habits which depend on simple associations, the well-trained dog acts or stops acting whenever a given signal is given. But most habits are chains of actions, bound to one another automatically, every link being the cue to its successor. Monkeys, white rats, squirrels, and sparrows learn the habit of hurrying into or out of a labyrinth of the Hampton Court pattern. In the case of rats we know that when they are learning the secret they may make use of hints from sight, smell, and touch, but when they have mastered the problem it seems that internal cues, coming from the muscles, the tendons, and the blood-vessels, take the place of the external cues, which are no longer needed.

15. Lastly, there is rational conduct exhibited in some of Man's activities. We have many reflex actions; we have a few instincts; we usually exhibit intelligent behaviour; we acquire habits; and occasionally we illustrate Reason. That means that the mind experiments with general ideas, without which the business in hand would not be possible. A spider makes its web *instinctively*; the ape uses a lever *intelligently*; but the engineers required *Reason* to build the Forth Bridge.

It seems that there are two great lines along which animal behaviour has evolved. On the one hand there is an entailing or engraining of aptitudes, so that the creature is ready with an appropriate answer when the situation arises. The moment the young rabbit hears the danger signal in the twilight, the thump on the ground with the hind legs, it makes a bolt for the burrow. The moment the nestling feels the touch of the caterpillar in its parent's mouth it gapes and then swallows. At the proper age the sight of the mouse pulls the trigger of the kitten's very definite mousing instinct, and effective action follows without any need of learning. There is much to be said for this racial registration of aptitudes, and we know the value of forming individual habits in playing games and in everyday work. To have the answer ready saves time and it usually means a more perfect answer than could be given for the first time on the spur of the moment even by a very intelligent creature. To have these reflex actions, tropisms, and instincts, *may* leave the creature more free for initiative or new departure. But the danger is of stereotyping behaviour, of its becoming too automatic. Thus it often happens that a creature with wonderfully perfect instincts, as among ants, is badly non-plussed by some slight change in circumstances.

The other line of evolution is that of experiment, where the animal tries something on its own in addition to the aptitudes with which it is endowed as part of its racial inheritance. A spider spins its particular pattern of web instinctively; it is to the manner born; but it may adjust special lines to keep the web firm in the wind, and that is an individual experiment. The thrush does not know instinctively how to deal with a wood snail, but it learns the trick of breaking the shell on a stone. For this kind of behaviour we must use some general word such as "experiment," "initiative," or "trial," for it may be illustrated by animals like starfishes which are below the level of intelligence.

Finally, when we think over the inclined plane of behaviour from the Amœba on the hunt

to the ape using a hammer to break the coco-nut, from the Slipper Animalcule reversing engines to the rooks letting the mussels fall so that they break on the stones, we see that the mental aspect, the inner life, becomes more conspicuous as we ascend. In simple animals it seems no more than a slender rill, in the highest animals it is a rushing stream.

LXVIII
EVOLUTION

§ 1
THE ABUNDANCE OF LIFE

WHEN Charles Darwin was between sixteen and seventeen years old he went to Edinburgh University to be a medical student; and in his first letter home he gave some of his impressions of the beautiful city. One of the sights that struck him most—"the most extraordinary thing I ever saw"—was the street called "The Bridges." For it crosses over other streets, and when the young student looked over the parapet, expecting to see a fine river, as he says, he saw far below a stream of people. Now that is what we are always discovering in Wild Nature—streams of life that cross one another, no corner unoccupied, mostly full of bustle. There are abundant creatures in the air—clouds of mosquitoes and midges, swarms of locusts, great flocks of birds; there are abundant creatures on the earth—a helter-skelter of rabbits in the warren, such a multitude of tiny frogs leaving the pond in early summer and making for the fields, that we can hardly get past without trampling on some of them. There are abundant animals beneath the ground—we counted forty earthworms' burrows in the circle we described on the golf-links by swinging our club right round at full length. In the Tropics the ants often pour into their underground passages like a living cataract. There are abundant animals in the waters that cover the earth—the salmon so crowded in the Canadian rivers that they choke one another, and the wayside pool so teeming with minute masterpieces that we cannot wonder at Tennyson's remark when he peered in: "What an imagination God has." Then there are the resources of the sea, the schools of porpoises, the shoals of fishes, and the animalcules on which larger creatures feed—so multitudinous that there may be more of them in a gallon of water than we count of stars on a clear night. Well might Spenser speak of

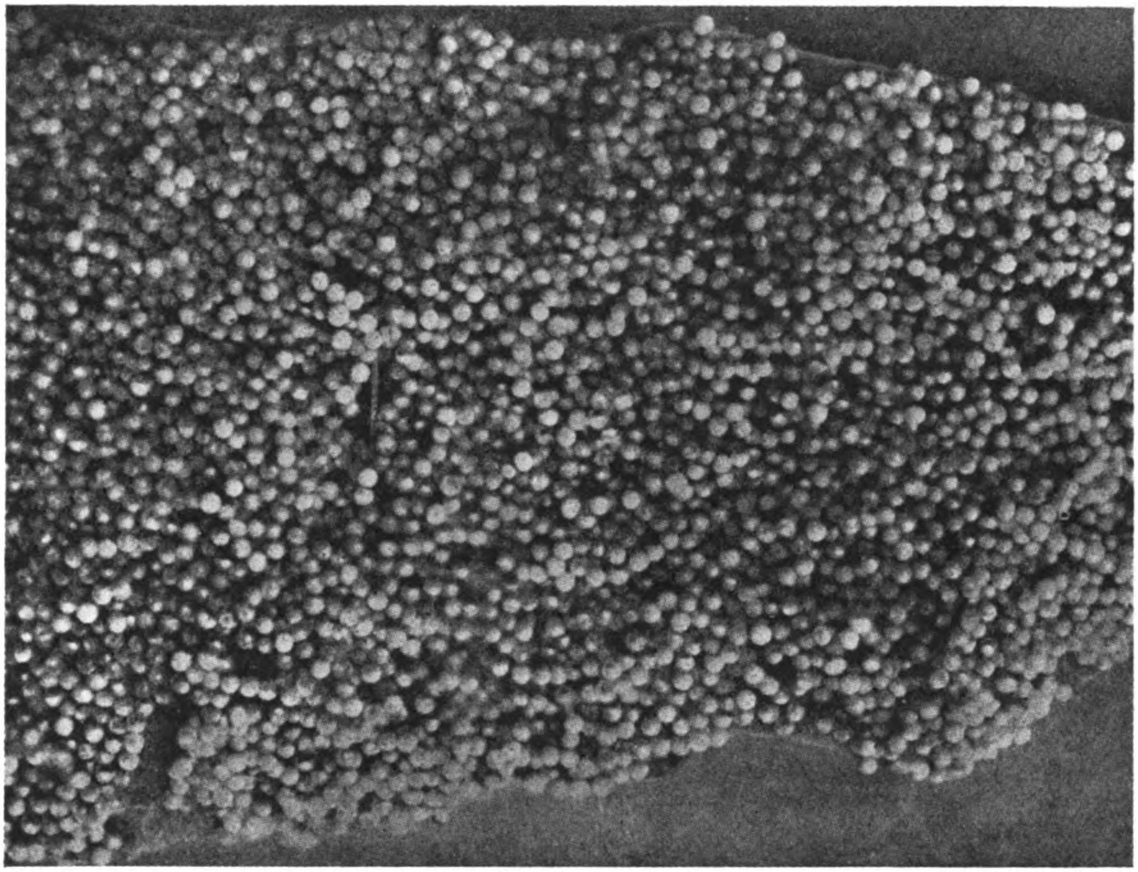
"The sea's abundant progeny,
Whose fruitful seede farre passeth those on land."

Or we might begin again with the Diatoms and other microscopic plants of the open sea, that form what Sir John Murray called "the floating sea-meadows," and picture along the plant line: of multitudinousness is the crowded zone of seaweeds in the shallow well-lighted waters; the dense growth among the mangrove trees on tropical shores—a rank vegetation sometimes breaking off to form floating islands; the luxuriant meadows where so many of the leaves grow upwards, parallel to one another, like the leaves of grasses, so that they do not overlap. There is the keen competition for standing-room, fresh air, and light that goes on in the jungle or the tropical forest, or, nearer home, in the hedgerow that has been left to itself. In plant-world as in animal-world there is the same *abundance of life*—an overflowing profusion.

There are two things to be distinguished—the multitude of individuals and the great variety of different kinds.

The Multitudes of Individuals.

A codfish is said to produce two million eggs, and it is plain that if all cods' eggs developed into codlings there would soon be an end of all the fishing, for the sea would be solid! There is one of the British starfishes (Luidia) which produces 200,000,000 eggs in a year. Huxley calculated that if the progeny of a mother Green Fly or Aphis all survived and multiplied they would, at the end of summer, suffice to weigh down the whole population of China. An oyster may have sixty



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EGGS OF HERRING FIXED TO SEAWEED.
(From a specimen in the Manchester Museum.)

The eggs of most of our marine food-fishes float near the surface, but those of the herring sink to the bottom and are attached to seaweeds, zoophytes, and stones. On an average the female herring produces 30,000 eggs in the season. Their diameter varies from a twentieth to a thirtieth of an inch.

million eggs, and the average American yield is sixteen millions. If all the progeny of one oyster survived and multiplied, its great-great-grandchildren would number sixty-six with thirty-three noughts after it, and the heap of shells would be eight times the size of the earth. We know that these possibilities do not happen because *the chances of death are many*; there is continual sifting and thinning. But when there is a vole-plague, or a march of lemmings, or a swarm of locusts, we get a glimpse of what ***might*** happen if there were not a Balance of Nature.

Some animals multiply much more quickly than others, and it is not always those that are most prolific that get on best. A mother toad may have seven thousand eggs, but all of these do not develop into tadpoles, and all the tadpoles do not change into toadlings, and all the toadlings do not become full-grown toads. The fact is that in many places the number of toads seems to remain very much the same year after year. Life is like the famous Mirza bridge: of the large number that begin to cross only a few get even half-way. Of most living creatures it must be said that the great majority die when they are very young. This is one of the big differences between man and ordinary animals. Man has learned how to avoid the severe thinning that goes on in Wild Nature.

The Passenger Pigeon.

Huge numbers do not always mean that a creature has a very strong foothold. This is well illustrated by the story of the Passenger Pigeon of North America, which flourished in millions not many years ago, and is now gone for ever! It was a strong handsome bird, living in great communities, and often forced to fly far

Photo: Ernest A. Botting.

GROUP OF FORAMINIFERA.

Many of these chalk-forming animals are about the size of small pinheads. In the majority the shell is made of lime, and there is great variety of architecture. In many forms, called Perforate, the shell is covered with minute pores, through which the living matter streams out in fine interlacing threads. In the other section, called Imperforate, there are no pores, and the living matter streams out at the mouth of the shell. The chalk cliffs of the past correspond to the Foraminiferal deposits now accumulating on the ocean floor.

every day to secure food-supplies. They say that in some of the forests there were great areas that served as nesting-places, sometimes with a hundred nests on one tree. Of one of these haunts, in the State of Kentucky, a description has been given by an American naturalist, Alexander Wilson. It was estimated to be towards forty miles in length and several miles in breadth, and to contain over two thousand million pigeons, which is more than the whole population of the globe. The pigeons used to arrive at their nesting-place about the 10th of April and leave with their young before the 25th of May, for they were migratory birds, shifting from one part of the country to another.

Mr. D. G. Elliot writes in "The Riverside Natural History" (1888): "The arrival of the great host is an impressive sight. Long before their crowded ranks appear, their approach is heralded by a sound resembling the rising of a gale of wind, increasing in loudness until the birds hurl themselves into their chosen nightly abode, when the din caused by the flapping of myriads of wings, the struggles for a place upon the trees, the constant change of position, and the crashing of overloaded branches, is so completely overpowering that not only the human voice cannot be heard, but even the discharge of a gun would pass unnoticed."

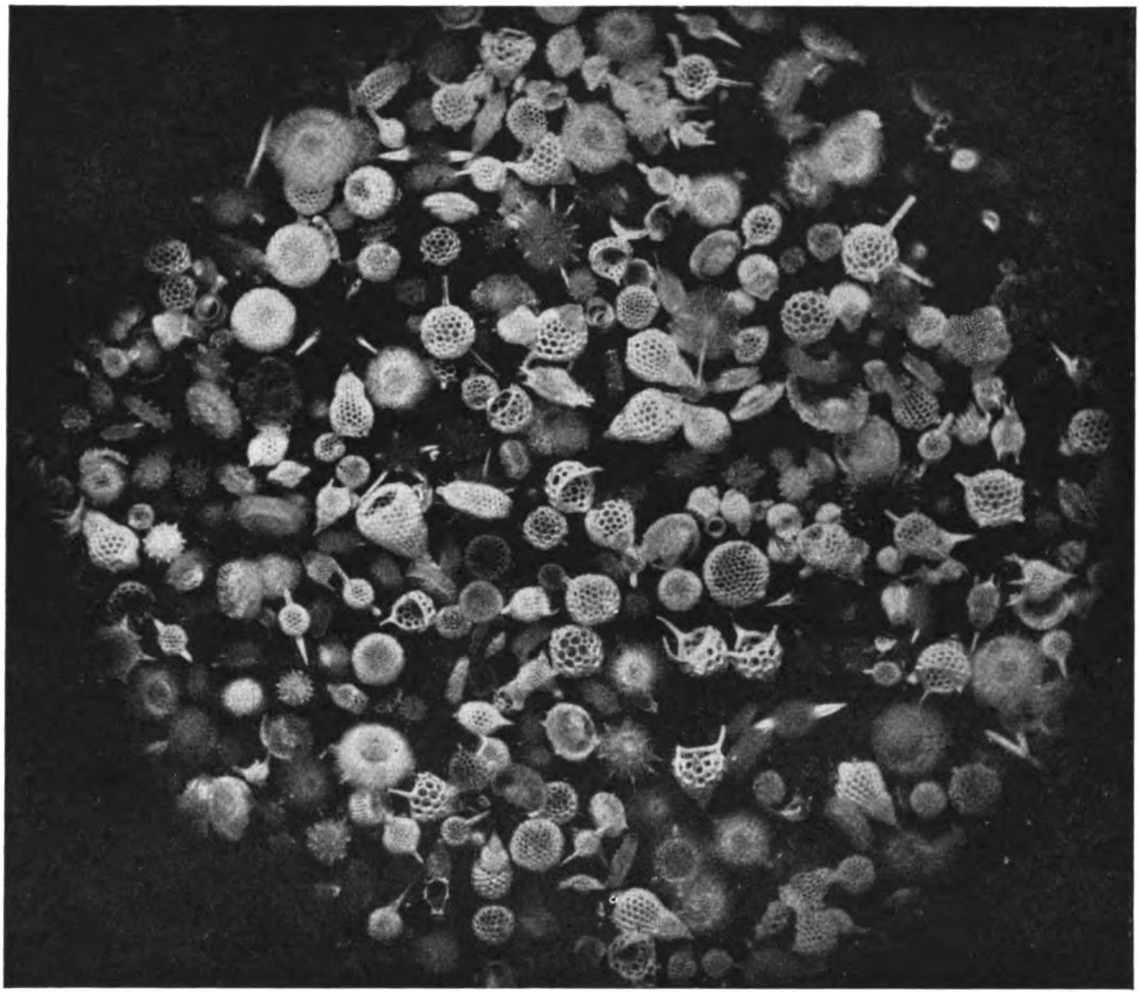


Photo : Ernest A. Botting.

POLYCYSTINA FROM BARBADOS DEPOSITS.

These extraordinarily beautiful shells, each about the size of a grain of finely sifted sugar, are the fossilised flinty skeletons of Radiolarians, which accumulated in Tertiary times on the floor of the Barbados Sea, and have since become dry deposits. The Miocene of Barbados contains at least 400 species of these Radiolarians, to which the general name Polycystina is often applied.

Birds of prey congregated over the roosting-places and picked fat squabs off the nests. Crowds of people came and encamped near " the immense nursery," and trees were cut down at the proper moment just before the young birds were able to fly. There was slaughter on a huge scale, and gradually, as the years passed, the ranks of the defenceless Passenger Pigeon were thinned, until, at last, all were gone.

The Passenger Pigeon, or " Wild Pigeon," as it was often called in America, was about the size of a turtle-dove, but with a long wedge-shaped tail. It had a remarkable power of rapid and sustained flight, often reaching a speed of a mile in a minute. The male showed a dark slate-colour above, purplish-bay beneath, and had rainbow-like neck-markings; the female showed drab colour above and dull white beneath. They did much harm in the fields, for instance, among the rice. But the chief interest of the Passenger Pigeon for us at present is that it was for a long time prodigiously abundant, sometimes darkening the sky, and yet in a few years it became an extinct species!

The Spreading of Weeds.

A grain of sand is in its proper place on the seashore, but when it gets into the works of our watch we call it dirt. Buttercups are in their proper place in the meadow and celandines in the wood, but both may be troublesome weeds in a garden. Some weeds are very beautiful; and when we call a plant a weed, we do not

mean that it is ugly. We mean that it has got out of its natural setting, and that it is spreading without the usual checks on its increase. We get another glimpse of the abundance of life when we notice how weeds run riot and smother better plants. If a garden is left to itself, the weeds will choke many of the flowers in a short time, and then other weeds will choke them. After a few years there may be nothing left except chickweed and bishop's-weed and other weeds.

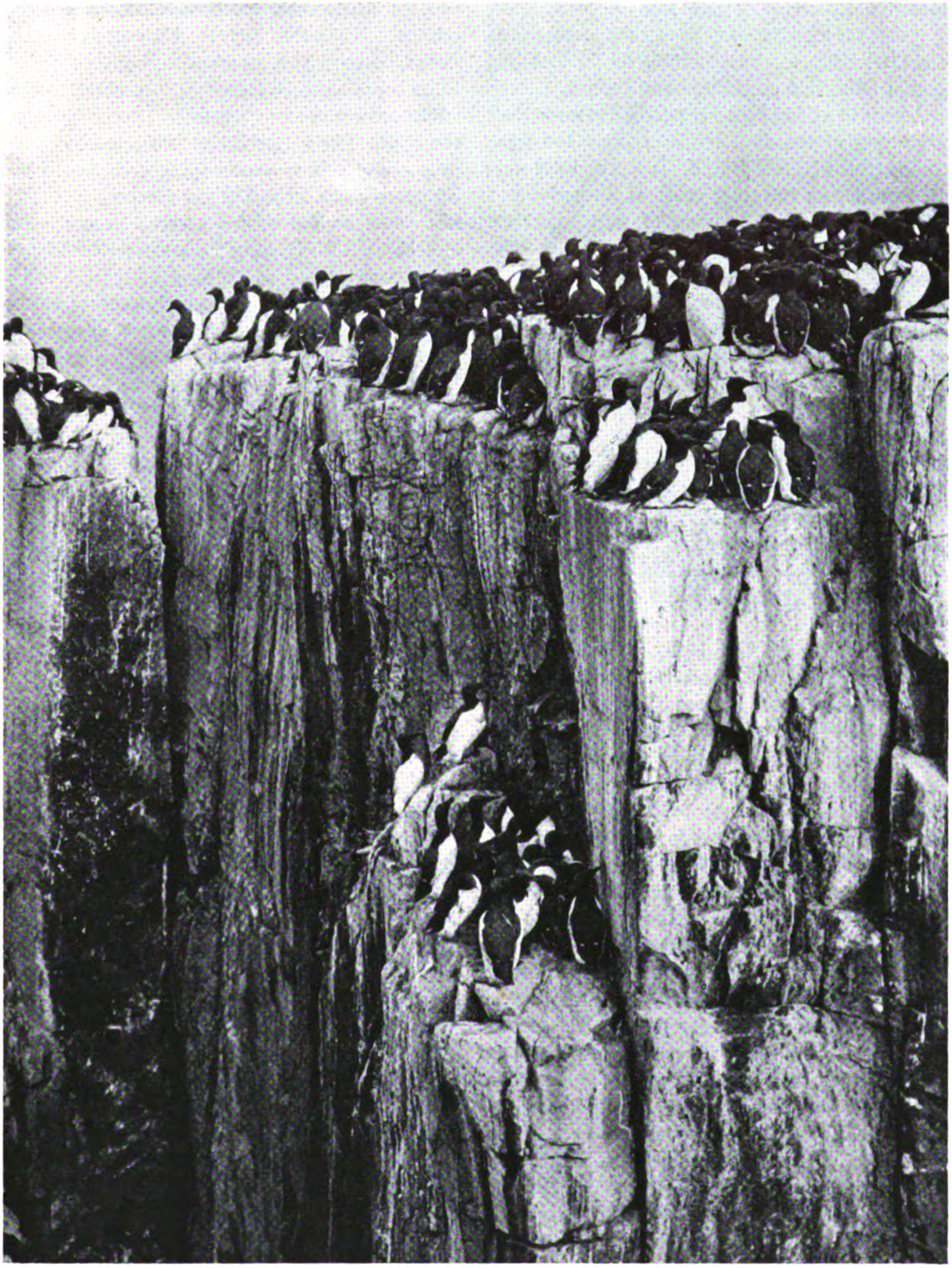
HEDGE MUSTARD (*Sisymbrium sophia*).
This common Cruciferous plant is represented in Britain by three very prolific species. One of these may have three-quarters of a million seeds! If all these germinated and the plants grew to maturity and produced others like themselves, the whole land-surface of the globe would be covered with hedge-mustard in three years. But this does not happen.

In his " Darwinism " (1899), Dr. Alfred Russel Wallace, Darwin's friend and fellow-worker, gives some good examples of the spreading of weeds. " Hundreds of square miles of the plains of La Plata are now covered with two or three species of European thistle, often to the exclusion of almost every other plant." The common watercress introduced into New Zealand has grown strong past telling; a stem may be twelve feet long and three-quarters of an inch in diameter. It sometimes chokes a river and causes serious floods; but the useful discovery has been made that if willows be planted on the banks their roots soon become so numerous in the bed of the stream that they crowd out the roots of the water-cress. Set a thief to catch a thief!

There is a common British plant (*Sisymbrium sophia*), one of the hedge-mustards, which often has 750,000 seeds. If all these sprouted and if the seedlings all grew up and bore seeds, and if this went on unchecked for three years, the whole surface of the earth—about 197 million square miles—would not suffice to contain the weed. We must not suppose, however, that weeds become dangerous simply because they have very numerous seeds, for there are many, such as buttercups, which bear only a few. Weeds become dangerous when they get into a new place where they are free from the sifting and singling that usually keep their numbers down. Suppose a plant had only two seeds and lived only for a year, it would be represented in twenty-one years by a progeny of 1,048,576 plants, provided that animals did not eat them, provided that their neighbours did not smother them, provided that all the seeds every year were properly scattered and landed in suitable places. Fortunately for us, these " provideds " do not happen.

A Visit to a Crowded Bird-Hill.

Just as we speak of icebergs—floating mountains of ice, separated off from the shore-ends of great glaciers, so we may conveniently speak of bird-bergs, meaning those great sea-cliffs, often islands, where birds nest in enormous numbers. There are many of them on or off northern coasts. For Britain we may name Flamborough Head, the Bass Rock, Ailsa Craig, Fowl's Heugh, and Foula. These places have this in common, that there are thousands of ledges and niches on which the birds can rest and nest; and these are



A BIRD-BERG AT FARNE ISLANDS, SHOWING ABUNDANCE OF LIFE.

The bird-cliffs at various parts of the British Coast, and even more frequently further north, afford fine illustrations of the abundance of life. At the breeding season they are crowded with guillemots, razorbills, and other summer visitors. In some places every ledge is occupied, and there is a struggle for standing room, as the photograph shows. Not very far off there must be good fishing—for the birds.

tenanted by more or less similar birds, some staying throughout the year, like cormorants and kittiwakes, others remaining for the breeding season only, like guillemots and puffins.

A visit to a good bird-berg gives one more than a glimpse of the abundance of life. We went to one called Handa Island. It lies about a mile off Scourie, on the west coast of Sutherland.

Handa is built of layers of sandstone and pudding-stone (conglomerate); it has a long grassy slope towards the mainland and precipitous cliffs to the north and west. To the north it looks on Greenland, to the west on the Butt of Lewis and the hills of Harris. The island feeds about 300 sheep and many rabbits. There used to be a few houses, but now there is only a shelter for the shepherd who comes over for six weeks at lambing time. We mention this because the small number of visitors accounts in part for the extraordinary tameness of the birds. They allow one to come within a few feet of them, but one must be careful of the precipices.

We climbed up the long grassy slope and came suddenly to the edge of a precipitous sea-cliff a hundred and fifty feet high, built up, like a giant's bookcase, of shelf after shelf of sandstone. The shelves were from a foot to a foot and a half in breadth, and they bore tens of thousands of birds, often packed so closely that their bodies were touching and their necks crossing. In most cases the various kinds of birds were quite separate, living, as it were, in different streets of "Cliff-Town." Lowest down there were kittiwake streets; then a guillemot or razorbill section with about thirty shelves one above the other; and then at the top, where the turf began, there were the burrows of the cheerful puffins. In some places there was a section of rock-face with guillemots only; in another place there were more razorbills, easily distinguished from their cousins by the compression of the bill from side to side. Here and there a kittiwake had established a claim to a broad bracket of rock projecting by itself, and sat there on its nest surrounded by thousands of guillemots.

We went higher and higher, walking carefully along the edge of the cliff—for who can tell when a slice will slide off?—and we came to a stretch of three hundred yards, where the cliff was four hundred feet high. We saw the abundance of life—the long terraces, tier above tier, of kittiwakes, guillemots, razorbills, and puffins. On some shelves the guillemots and razorbills were able to stand upright with their white breasts turned seawards, but most had their backs outwards and their bodies pressed against the rock. The long webbed feet must be of use in gripping a downward sloping shelf, but it was interesting to notice that the foothold was often lost when an extra bird arrived from the sea and insisted on landing on a shelf already full. There was plenty of fighting and murmuring, and the noise was sometimes deafening, but on the whole it was a good-humoured crowd, and there seemed to be a good deal of give and take. We saw nothing like interference with the young birds, who were nearly ready to fly away. It was difficult to believe that in a few days there would not be a single guillemot, or razorbill, or puffin left on the cliff. All disappear before the end of July, making for the open sea and the coasts of southern lands. For the three birds we have named are only summer visitors to Britain.

On a section of the cliff, 400 feet high and about 300 yards in length, we tried to make some rough estimate of the number of birds, and our conclusion was that there were 400,000 at least. Why were there so many? The first part of the answer is that as the number of suitably shelved cliffs is not very great, birds gather from far and near, and return season after season. The second part of the answer is that the birds have few enemies except man. The sea-eagle or erne is now very rare; the buzzards, which still frequent Scourie, can hardly venture among the legions of sharp-billed guillemots; and it is not likely that the greedy Great Black-backed Gulls, that we saw sailing about, get more than the weaklings. Some of the young birds fall off the shelves or may come to grief when they make their first venture on the sea, but on the whole they do very well; and it should be remembered that guillemots, razorbills, and puffins lay only one egg at a time. But the third part of the answer is simply that there are so many fishes in the sea. The multitudes of fishes—we saw the birds carrying them in their bills as food for the young ones—make the multitudes of birds possible. And the fishes depend upon crustaceans, and these on microscopic animals and plants. That is how the world goes round!

A WONDERFUL SPECTACLE.

The abundance of life is well illustrated by the vast congregations of flamingoes that are sometimes seen. At Lake Hannington, in Central Africa, the sheet of water, some six miles long and two miles broad, may be quite covered with literal millions of these beautiful pink birds. The African species (*Phœnicopterus roseus*) has been seen three or four times as a straggler in Britain.

The Great Variety of Different Kinds.

There is something impressive in an enormous flock of sheep that takes an hour to pass by, or in a huge congregation of rooks darkening a field, or in thousands of starlings swirling above their resting-place for the night like clouds of hot dust from the crater of a volcano, or in a shoal of mackerel, or in a swarm of bees, or in the thronging multitudes of ants that we see in a big ant-hill, or in a fleet of jellyfishes through which we row the boat all the afternoon, but there is something much more interesting than the dense peopling of some corner by one kind of creature. What is much more interesting is the variety of different kinds of creatures. To take a very moderate estimate, there are 25,000 different kinds of living backboned animals (or Vertebrates), named and known, including mammals, birds, reptiles, amphibians, and fishes. And to this long list must be added a huge number of extinct backboned animals, especially fishes, which are only known as fossils in the rocks—the graveyards of the buried past.

But when we turn to Backboneless Animals (or Invertebrates), the number of different kinds, named and known, is enormously greater, it is at least a quarter of a million. It must be admitted, however, that four-fifths of these are jointed-footed animals, especially insects, but that leaves 50,000 for molluscs, worms, star-fishes, stinging animals, sponges, and single-celled creatures. To this huge Invertebrate list there must again be added a vast number of fossil animals, which have had their day and ceased to be.

On a clear night one can see between four thousand and five thousand stars with the unaided eye, but as many new kinds of insects are sometimes discovered in a single year. Or, we may say that there are one-tenth as many different kinds of birds on the British list as we can see of stars on a clear night. The British list stands at present at about 460 different kinds of birds—many of them great rarities.

It may be interesting to give a few details of the census of living animals, but it must be

understood that the figures are only approximations:

Backboned Animals	Mammals ...	2,850	25,000 species.
	Birds	10,000	
	Reptiles... ...	3,500	
	Amphibians ...	1,000	
	Fishes	7,500	

Backboneless Animals: 250,000 species.

As for plants, there are said to be about 50,000 named and known, and of these about half are flowering plants. Thus we see that there are far more different kinds of animals than there are of plants; but when a particular kind of plant, such as a grass, finds a very suitable place, the number of individuals soon comes to be far in excess of anything that is to be found among the larger animals. One of the reasons why there is greater variety among animals than among plants is simply this, that the great majority of plants (making exceptions for those that live in water and those that are perched on other plants) must be rooted in the ground. There are not open to them so many "chances," so many niches of opportunity, as are open to animals that can move about and burrow and climb and fly. In other words, experiments pay better among animals than among plants. It may be said that most plants play a waiting game, though they also have their ventures—in the Venus Fly-Trap for instance.

Photo: H. J. Shepstone.

LOCUSTS SETTLED ON OLIVE TREES FOR THE NIGHT.

These are young locusts which have just completed their last moult and become flying insects. The migratory species move from place to place, first on foot and then on wing. The numbers in a swarm may be prodigious, and every green thing may be cleared off in a few hours.

Large numbers do not really make much impression on us. It is more useful to go out with a botanist and sit down on the links, and then without rising he will often be able to show you a dozen quite different kinds of plants within reach. After walking for a mile to another sort of place he will do the same thing again, but it will be another dozen plants this time! If you sit down on the dry sand of the shore near the high-tide mark, you may quite easily find within reach of your arm a dozen different kinds of small animals, or parts of them at least. We once dredged up a stone with fourteen different kinds of animals fixed to it!

Fossil Animals and Lost Races.

There are two rather difficult points that require clearing up. There are some fossils in the rocks which have their living counterparts in the sea to-day. Such is the Lamp-Shell Lingula, which flourished millions of years ago and is flourishing still. No one would count in the census both the living animal and the fossil, for that would be counting the same creature twice. But there are fossilised animals which were the ancestors of some animals now living, and are more

or less different. Thus three-toed extinct horses were the ancestors of the modern horse which walks and runs and jumps on the tip-toe of one digit in each limb. It is clear that the three-toed horses must go down on the list as well as the living kinds of horse. There is a very interesting Mudfish in Queensland rivers called Neo-Ceratodus, which breathes by a lung as well as by gills, and helps to link fishes to amphibians. Now this curious double-breather was represented long ages ago by a slightly simpler ancestor called Ceratodus, and both must be entered on the census paper. Once more, there are in the fossil-bearing rocks not a few extinct animals which are not known to have any living descendants to-day. They represent *lost races*; they have been blotted out entirely. Such, for instance, are the Flying Dragons, which did *not* lead on to birds, and the Fish-Lizards, and the ancient Sea-Serpents, and the huge Sea-Scorpions. But they must be included in the Roll of Honour. They were once as living as we are. Is it quite clear, then, that fossils may be (1) the petrified remains of animals that lived long ago but are carrying on still; that they may be (2) the ancestors of present-day kinds: and that they may be (3) the remains of lost races which have no direct descendants in the Animal Kingdom of the present day?

The second difficult point is this: What do we mean by "a kind"? What is it that we count in the census of animals and plants? A kind or *species* means a group of individuals that agree in many features and show these with some constancy generation after generation.

What is a Species?

The members of a kind or species can all breed among themselves, but they do not readily breed with related species. Thus hares and rabbits never cross. And the features in which the members of a kind or species agree, and on account of which they get a special name, must always be bigger than the individual features that distinguish the members of a single family. There are many different colours of shore-crabs, but it would never do to give these different species names, for the same differences in colour may be found among the brothers and sisters of a family. The peculiarities of a species must be important enough and constant enough to deserve a special name. That special name is always written second: thus Passer *domesticus* is the House Sparrow as distinguished from Passer *montanus*, the Tree-Sparrow. Thus Felis *leo* is the lion, Felis *tigris* the tiger, Felis *catus* the Wild Cat, and so on—different kinds of "cats" within the larger group or genus Felis. Sometimes there is only one species in a genus—thus there is only one "New Zealand Lizard" (Sphenodon); or one species of a genus in the country, thus there is in Britain only one kind of kingfisher (*Alcedo hispida*). The difficulty is when there are many nearly related kinds, say of trout and char, bramble and willow. Then naturalists begin to quarrel about what a "good species" is.

§ 2

THE PEOPLING OF SEA AND LAND

ALL the world is a stage, and on that stage for many millions of years there has been played the drama of animal life. The actors have changed in the course of ages—becoming on the whole finer, and the stage has changed—becoming in many ways more beautiful; and the plot has changed—becoming more and more intricate. But while everything changes there is a sense in which everything remains the same. The stage is the same old earth, the actors and actresses are living creatures all akin, and the acting never gets very far away from the two great motives of Hunger and Love. As the poet has said: "While philosophers are disputing, hunger and love solve the world's problems."

Always, at any rate, we have to do with three great things: the stage, the actors and the acting. In the language of Biology, the three great facts are ENVIRONMENT, FUNCTION, ORGANISMS.

The kind of activity which we call "living," which is so difficult to understand, consists mainly in thrust and parry between plants and

animals and their surroundings. But as we ascend the scale, the inner life of thinking, feeling, and willing counts for more and more.

The Changing Stage.

As we watch a countryside from year to year, we see changes going on—more marked in some parts of the country than in others. An old naturalist once showed us a little island in a river, an island with willows and alders on it, and told us that he had seen that island grow from nothing in the course of his life.

Sometimes a flood changes the appearance of a great stretch of valley and alters the course of the river. Sometimes a forest fire spoils everything for many a year, changing the plants and animals as well as the general appearance of the region. Sometimes a severe storm takes a big slice off the cliffs or buries several farms in sand. If such changes can be seen in a short time, we can understand that a great deal may happen in many millions of years. This is very important, because part of the drama of life consists of the answers-back that living creatures make to the changes in their surroundings.

The rain caught in the crevices of the rocks freezes and bursts the fissures as if by a thousand wedges; runlets of water carry away the fragments and grind them into sand in the bed of the stream; the sea hurls stones against the base of the cliff and we can hear them grinding against one another; the glacier carves out a valley and gouges out a lake; and on a larger scale, there are volcanic eruptions and bucklings of the earth's crust. In scores of ways—a great study in itself—the surface of the earth has changed from age to age, and what is weathered off at one place is laid down somewhere else to form the raw materials of rocks that are yet to be. Given enough of time, and the mountains will flow down to the sea, and dry land will appear in the midst of the ocean.

The stage was not very promising to begin with:

They say

"The solid earth on which we tread
In tracts of fluent heat began,
And grew to seeming random forms,
The seeming prey of cyclic storms."

Our first picture is the smoking, cindery crust of the cooling earth—not yet fit to be a home of life. Even the atmosphere was depressing, for it consisted mainly of carbonic acid gas, water vapour, and nitrogen. There was very little oxygen, for most of the atmospheric oxygen, on which almost all living creatures depend, has been made from CO_2 by green plants working in the sunlight.

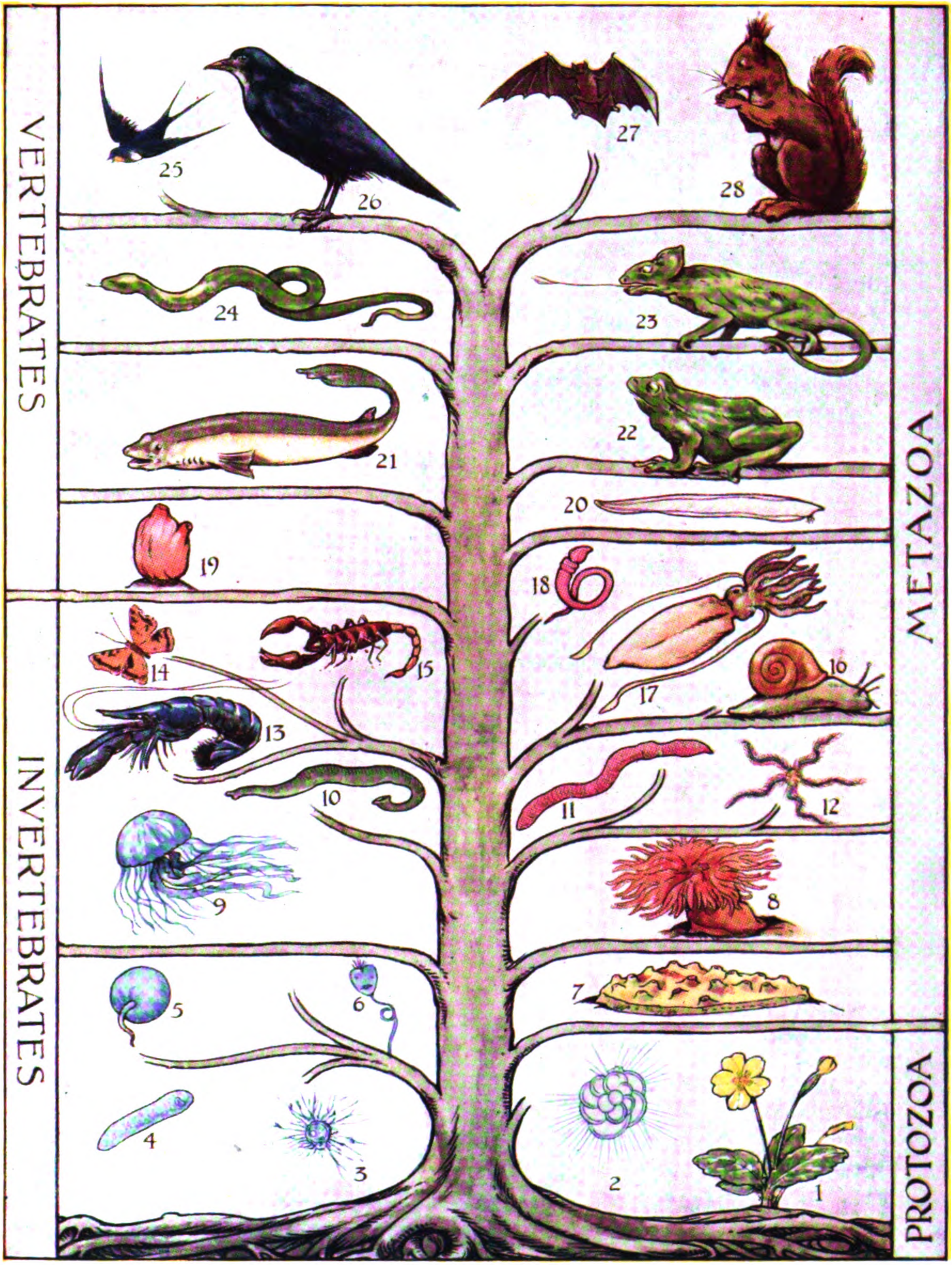
The appearance of Living Creatures.

But the crust of the earth became cooler and water vapour was condensed into little pools of water. These grew and flowed together into great seas, which dissolved salts out of the crust. Perhaps those authorities are right who believe in a period of universal ocean covering the whole earth. But whether we picture one great ocean or many seas matters little, we must add to our picture crowds of minute forms of life, betwixt-and-between creatures, half plants half animals, swimming about in the water. We do not know how they came into being. They fed on air, water, and salts; and they began the process, on which everything else depends, of splitting up CO_2, fixing the carbon, and liberating the oxygen. It has been recently discovered that if certain rays of light be passed slowly through a mixture of water and carbonic acid gas (carbon dioxide) there is formed a simple carbon compound (CH_2O) called formaldehyde. This was what the first living creatures learned to do, millions of years ago, and this is what every green leaf is doing every day.

The Primitive Vegetation.

By a buckling of parts of the crust of the earth, continents were formed and deeps between. In the shallow waters near shore a new opportunity was offered; it became possible for some of the more plant-like primitive creatures to settle down without losing the light. They would begin to grow out into threads and plates; the race of seaweeds began, and everyone should make an expedition to the seashore rocks at the lowest tide to get a good view of this very ancient, very varied and beautiful vegetation.

Some of the simple plants might gradually find their way through estuaries and swamps into fresh waters, and thence as liverworts, mosses, ferns, on to more or less dry land, where eventually flowering plants appeared. But there are some botanists, like Dr. A. H. Church, who believe that when a slow raising of the beach occurred, and it happened often, there came



PICTORIAL REPRESENTATION OF THE GENEALOGICAL TREE OF ANIMALS.

1. A plant, hinting at the Vegetable Kingdom—on a very different line of evolution.—2 and 3. Chalk-forming Foraminifers.—4. A parasitic Gregarine.—5. The Night-light Infusorian, Noctiluca.—6. The Bell-Animalcule, Vorticella. All these are unicellular animals—all the rest are multi-cellular.—7. Crumb-of-Bread Sponge, with exhalant openings like craters of volcanoes.—8. A Sea-Anemone, and 9. A Jelly-fish—both Cœlentera or Stinging Animals.—10. A Leech, and 11. An Earthworm, both Annelids.—12. A Brittle-Star, one of the Echinoderms.—13. A Lobster, representing Crustacea.—14. A Butterfly, representing Insects.—15. A Scorpion, one of the heterogeneous class of Arachnids.—16. A Snail, and 17. A Cuttlefish, both Molluscs.—18. Balanoglossus, a worm-like type intermediate between Invertebrates and Vertebrates, a border-line animal.

Among Vertebrates: 19. A Sea-Squirt or Tunicate.—20. A Lancelet—a pioneer Vertebrate.—21. A Shark (Fishes).—22. A Frog (Amphibians).—23. A Chamæleon, representing the Lizard order of Reptiles.—24. A Snake, another type of Reptile.—25. Swallow, and 26. Rook, representing Birds.—27. Bat, and 28. Squirrel, representing Mammals.

The genealogical tree may be said to fork at the top, for Birds and Mammals are on divergent lines of evolution. Both had their origin in extinct reptiles. The relatively more active types are to the left side throughout.

about a gradual transformation of some of the higher seaweeds into land-plants with true roots and leaves. In any case, water-plants gave rise in the course of ages to land-plants.

But we must go back again to the shallow waters near shore. For it is highly probable—that is all we dare say—that among the simple creatures that were beginning to be thorough-going plants, there arose another kind of creature, the first thorough-going animals. They were predatory; they could no longer feed on air, water and salts; they stole what the plants had manufactured. As they fed on complex ready-made food, like sugar and other carbon compounds, they gained a great deal of energy and began to live a stirring life. They tried experiments along many lines and gave rise to sponges, zoophytes, corals and jellyfishes, and in the course of ages to all the great abundance of the sea.

The First Animals.

It is probable that the first animals lived in shallow water near shore, creeping or swimming about among the seaweeds. But some naturalists think that animals began in the open water farther out. We cannot decide between these two views, but it seems safe to say that the cradle of life was either the Open Sea or Near Shore. The original home could not be the dark floor of the sea, for that is too difficult a place for the beginnings of life. It is too much shut off from the sun, which is the great source of power. We may also exclude the dry land, for that is a difficult home for simple forms of animal life; indeed it was not a place for animals to live in until plants led the way.

Beginnings of Animal Life in the Sea.

We may venture to say that every race of animals that has got on well on land came from a stock that served a long apprenticeship in the water. Mammals and Birds sprang from

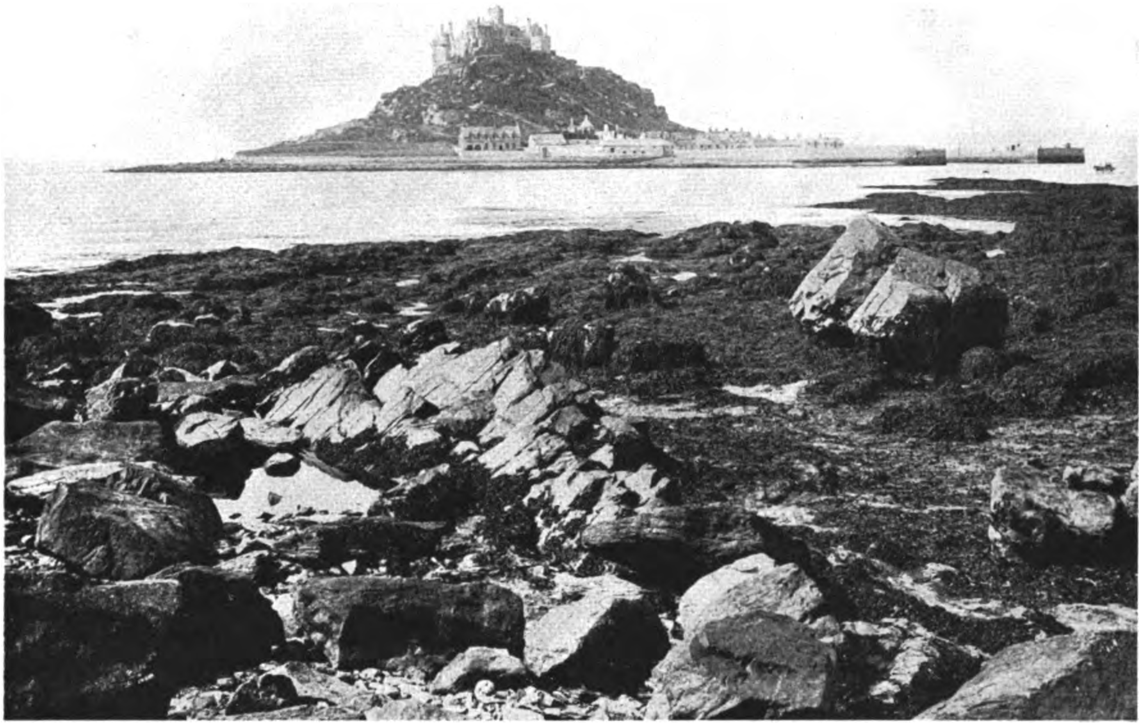


Photo: Messrs. Gibson & Sons, Penzance.

SEAWEEDS ON THE ROCKS AT MOUNT'S BAY, PENZANCE.

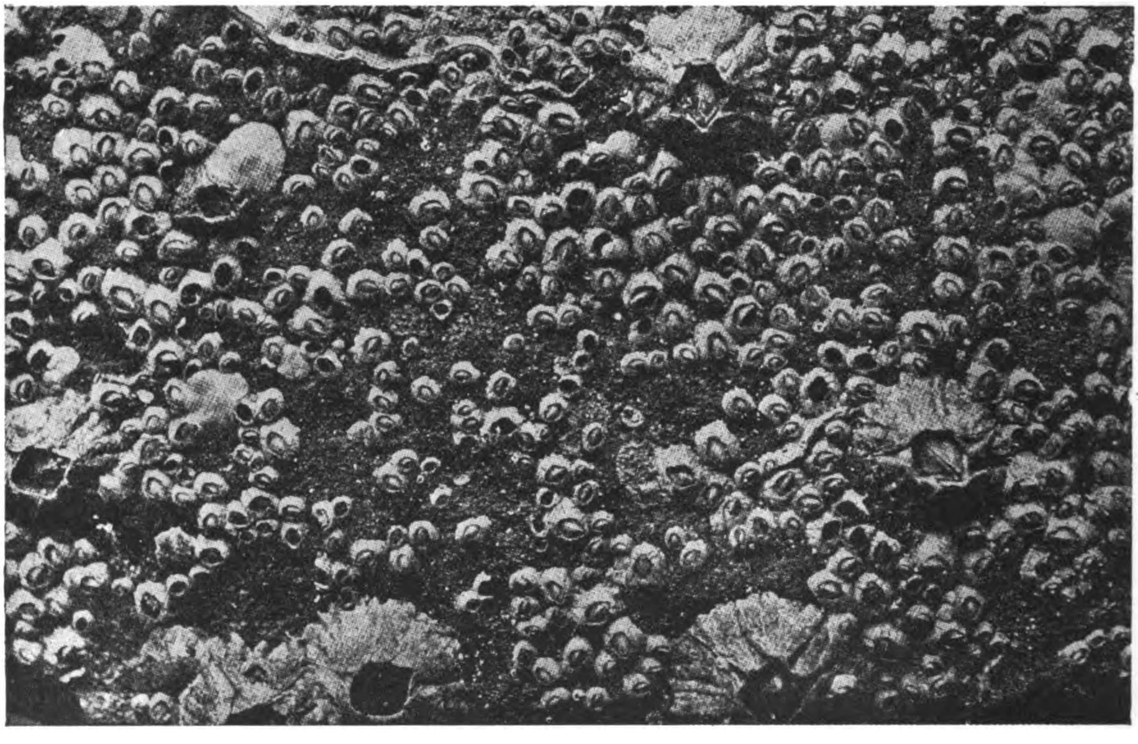
There is something very impressive in a good view of the abundance of seaweeds exposed at very low tide, for not only is there an unexpectedness in the crowded life, but there is a suggestion of the archaic. The seaweed vegetation was long anteeedent to the terrestiial vegetation. It may be that some of the highly-evolved seaweeds became ancestral land-plants

Reptiles, Reptiles from Amphibians (half in water, half on land), and Amphibians from Fishes—which can rarely leave the water except for a short time.

There remains the possibility that the simplest kinds of animals began in fresh water, but there are some reasons against this view. The oldest fossil-plants are seaweeds, and the place where the plants began must have been the place where the animals began. The oldest animal fossils in the rocks are mostly related to animals that now live in the sea, such as jellyfishes, corals, sea-lilies, and lamp-shells. If you enquire into the first animals that gained true bodies, namely the sponges, you find that there are many hundreds of different kinds in the sea, but there is only one family of sponges in fresh water. That tells a tale. If you enquire into the next great group of animals, namely, the Stinging Animals, you find that there are thousands of different kinds in the sea—zoophytes, swimming-bells, jelly-fishes, sea-anemones, and corals—but only about half a dozen different kinds in fresh water. This also tells a tale. *The sea is the original home.*

One other argument, and a curious one. When we cut our finger and put it to our mouth we find that the blood has a salt taste. There are several salts carried in solution in the blood, and they are the salts that are commonest in sea water. Moreover, the proportions in which the various salts occur in the blood are very nearly the same as the proportions in which these salts occur in sea water. This must mean that when blood was first set apart very long ago as an internal fluid in the body of animals, it was a fluid not very different from sea water except in this that it contained dissolved food. It is difficult to avoid the conclusion that the first animals with blood, represented to-day by worms called Ribbon Worms (or Nemertines), lived in the sea.

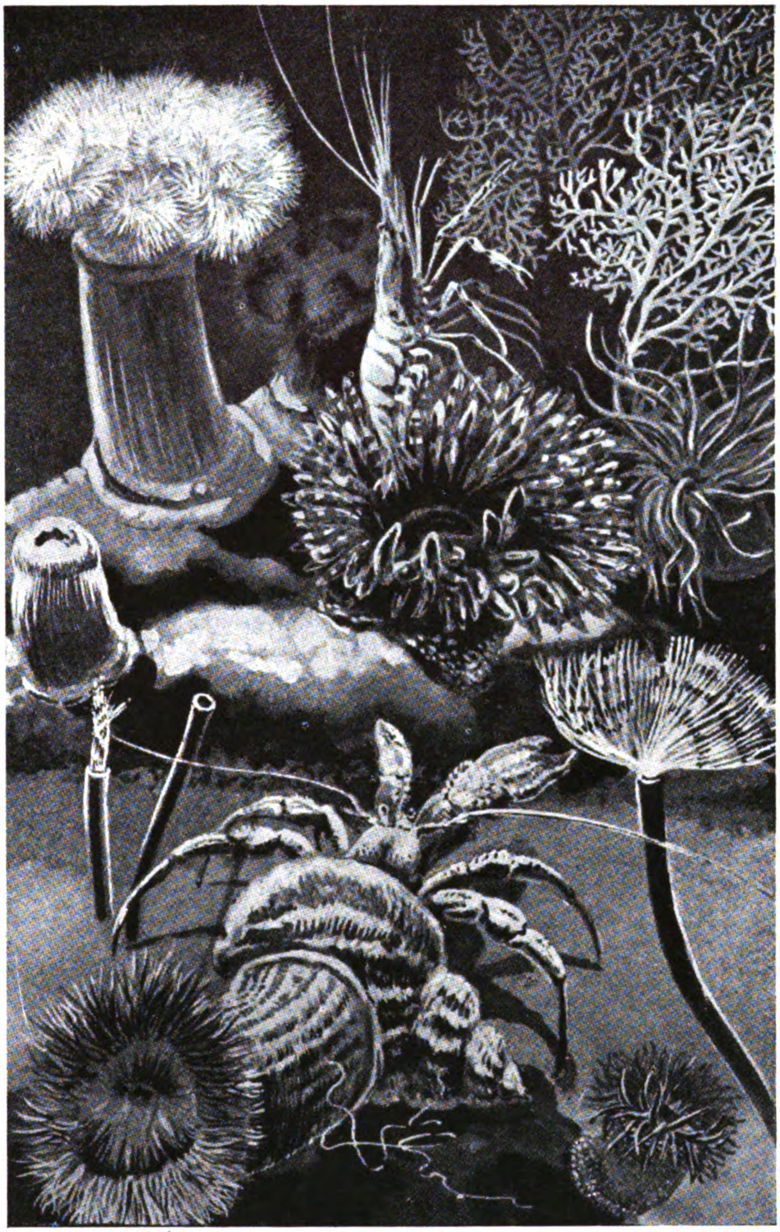
It comes to this then, that to our question: Where did animals begin? we must give the answer: They began in the sea, either in the Open Sea or in the shallow water near shore among the seaweed. Our own view is that the first living creatures to be very successful were Open Sea creatures, half plants half animals, able to swim about by means of an undulating



ACORN BARNACLES ON ROCK (*Balanus antinnabulum*).

These fixed crustaceans, belonging to the order Cirripedia (curl-footed), start as free-swimming larvæ. They settle down on their heads and begin to waft their microscopic food into their mouth by means of six pairs of two-branched feet or thoracic appendages. On the outside there is a rampart of six shell-pieces, which can increase in size. On the up-turned ventral surface of the animal itself, there are two pairs of calcareous platelets.

living lash (or flagellum), and able to feed on air, water and salts. At a later stage, after seaweeds had begun to flourish on the floor of the shallow water, there arose the first animals—living on minute plants and on the microscopic fragments of plants. In the Open Sea to-day there are vast numbers of lashed organisms or Flagellates which seem still hesitating between the Vegetable and the Animal Kingdoms.



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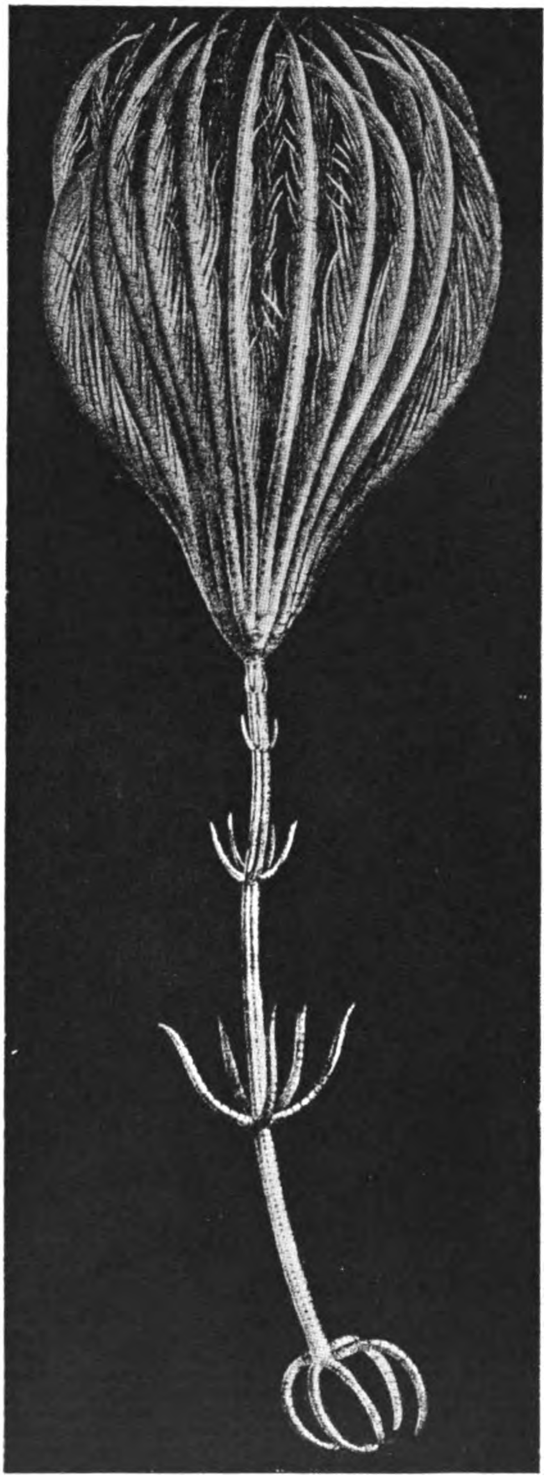
A GROUP OF SEA-ANEMONES.

In the foreground there is the mutually beneficial partnership or commensalism between a hermit-crab (*Eupagarus bernhardus*) and a sea-anemone (*Sagartia parasitica*). In the background, to the left, there is a beautiful Plumose sea-anemone (*Actinoloba dianthus*), with a frilled or puckered disc bearing very numerous delicate tentacles. Three other kinds of sea-anemone (Dahlia, Opelet, and Strawberry) are shown; in the background to the right there is a Sea-Fan, a colony of small, somewhat sea-anemone-like polyps, with a branched central axis. In front of this there is a prawn, and the antennæ of the hermit-crab touch two tube-worms, one of them with an expanded wreath of gill-filaments on its head.

The spreading of Life in the Sea.

If the first genuine animals began among the seaweeds in the well-lighted shallow water near shore, their first enterprises had to do with making the most of their territory. For there are different zones in the shore area, and each zone in turn was explored and colonised. Thus there were some animals that got on best among the red seaweeds which grow farthest down the sloping floor. Others flourished better among the brown seaweeds, like the tangles and the kelp. Others, that wanted all the light they could get, settled down among the green seaweeds, like sea-lettuce, in the shore pools. It may be explained that *all* the seaweeds have *green* colouring matter (chlorophyll), by means of which they are able to utilise the sunlight, but it is masked in the browns and reds by other pigments. Finally, the most adventurous animals of the seashore area found their way into the zone between tide-marks, and obviously the only kinds that could flourish there would be those that were able to endure being left high and dry when the tide is out, as we see to-day in limpets, whelks, acorn-shells, and many more.

Many of the sea-shore animals are fixed, like sponges and zoophytes and sea-anemones, but



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THOMSON'S SEA-LILY (*Endoxocrinus wyvillethomsoni*).

This graceful stalked Feather-star or Sea-Lily is a member of the Pentacrinid family of Crinoids. Its natural colour is grass-green. The animal lives in deep water, fastened to the sea-floor, but the stem of the full-grown Pentacrinid breaks across, and the animal can swim about, dragging part of the stem with it, and using it to effect temporary attachment.

others are swimmers, and it would naturally come about that some of these would venture farther and farther from the land and become Open Sea animals. There would be two great inducements: first that much of the floating food tends to be swept out to sea; and, second, that the Open Sea is a quieter and less upsetting place than the shore.

But there is another way in which additions might be made to the Open Sea population. Many shore animals have young stages that swim out or get carried out to sea. This is well, for they are too delicate to stand the rough-and-tumble life of the shore, the hammering of waves and tides. Thus the young stages of shore-crabs, acorn-shells, starfishes, sea-urchins, and many more spend the early part of their life in the open waters, returning to the shore when they are fully-formed and tougher in build. Now it may be that some of these Open Sea young stages (pelagic larvæ, as they are technically called) remained in the open waters and started a new type of animal suited to that kind of life. Of course this would not happen quickly, but it might happen in the course of time. There are some animals of the Open Sea which look a little like children that have not grown up (permanent larvæ). Such, for instance, is Trochosphæra, which is very like the trochosphere larva of a sea-worm.

Let us take another, slightly different, illustration. Many of the plant-like Zoophytes (or Hydroids) of the shore-area bud off in the summer season beautiful swimming-bells (or Medusoids), which are often set adrift. They swim about by pulsating their bell, and they are almost as clear as the water itself. But one can sometimes see the mouth hanging down, like the clapper in the middle of the bell. Many of these Swimming Bells are not bigger than black-currants, but some are the size of walnuts or larger. Their tentacles have stinging cells which benumb and grapple the minute animals on which the Swimming Bells feed.

Now these Swimming Bells produce eggs and male elements, and from the fertilised eggs there develop free-swimming embryos. Eventually the young forms, which are very minute, settle down on stones and shells and seaweeds in in-shore waters, and grow, by budding and budding hundreds of times, into the colonies that are

called zoophytes. The story is an intricate one, but of great interest.

ZOOPHYTE → BUDS OFF SWIMMING BELLS → WHOSE FERTILISED EGGS DEVELOP INTO FREE EMBRYOS → WHICH SETTLE DOWN AND GROW, BY BUDDING, INTO → ZOOPHYTES.

This is what is called *alternation of generations*, and it has a curious parallel in the life-histories of Mosses and Ferns.

But the point at present is this, that there are in the Open Sea a number of animals like Swimming Bells, but having no connection with zoophytes. It is possible that these arose from Medusoids which suppressed the sedentary zoophyte stage altogether, and, as it were, severed their connection with the shore. Among animals with complicated life-histories we can often discover a tendency to lengthen out one chapter and telescope down another.

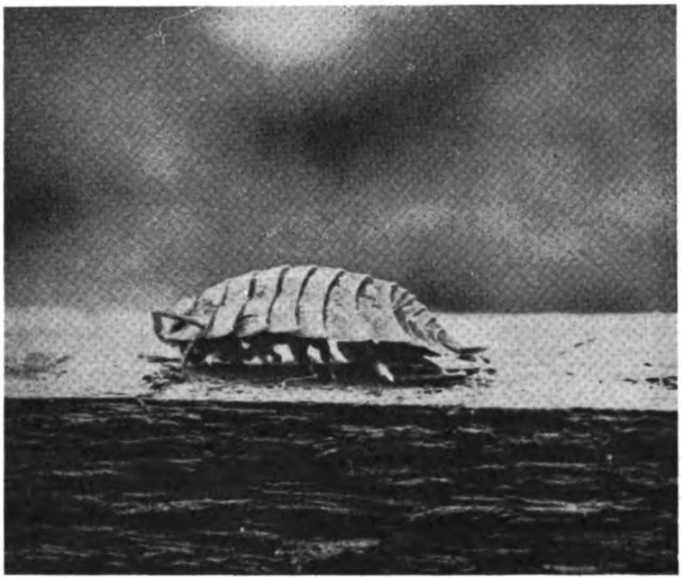


Photo: John J. Ward, F.E.S.

WOOD-LOUSE (Porcellio).

Wood-lice are flattened terrestrial crustaceans that have left the water. They are included in the order of Isopods, sub-order Oniscoidea. The number of appendages is the same as in lobsters, prawns, and crayfishes, namely nineteen pairs. The abdominal limbs are traversed by minute tubes which serve for breathing moist air.

From the end of the well-lighted shallow waters, and that means the end of the seaweeds, the floor of the sea slopes down, sometimes gradually, sometimes steeply, to the great depths. At a certain distance on the downward slope there is "the mud-line," the last zone where there is an abundant deposit of the fine sediment from the shore. The deposit consists partly of rock-dust and partly of minute particles broken from seaweeds and shore animals, both living and dead. In the deposits of this "mud-line" there is a great congregation of animals, such as worms and bivalves, brittle-stars and sea-cucumbers. They are chiefly what may be called "soft-mouthed" animals which feed on minute organisms or particles, in contrast to "hard-mouthed" animals, like crabs and cuttlefishes, which have strong jaws suited for eating what is hard or tough.

As the "crumbs" of the shore sank farther and farther down the slope, some shore animals followed them, and became suited to living in the dark, cold water of the great depths. It was in this way, we believe, that the animals of the Deep Sea originated, for there is often a distinct relationship between the animals in the great depths and those living in the nearest shore waters. Sometimes, moreover, a section of the crust of the earth was depressed and a stretch of shore gradually sank into deep water, and this might be another way in which Deep Sea animals began. But it should be noticed that only a few of the animals now living in the great abysses of the ocean can be regarded as very old-fashioned or primitive.

The Common Flounder is often found up rivers at a distance of a dozen or more miles from the sea. This is very interesting, for most of the Flounder's relatives, like the Sole and the Plaice, are confined to the salt water, and there can be no doubt that the Flounder was originally a sea fish. It is learning to live in fresh water, but it has to go to the sea to spawn, and the early life has to be passed in the sea; but the story of the Flounder shows us how the colonising of the fresh waters might *begin*. If a fish, making experiments like the Flounder, should learn in the course of time to spawn and develop in fresh water, that would help still further to clear up the rest of the problem:

The Colonising of the Fresh Waters.

How were the fresh waters peopled? The supposition we have made is not a wild one, for there are some fishes that can stand both salt water and fresh. Thus the Three-spined Stickleback makes its nest in ponds and rivers, but it may also be found in shore pools and in the sea itself. There are other fishes, such as the Salmon, Shad and Sea Trout that can pass from salt water to fresh, and this was one of the ways in which the fresh waters were peopled.

Another thing that may sometimes have happened is this: an arm of the sea might, by changes of level, come to form an inland lake, whose waters might gradually become fresh through the inflow of streams and under the influence of aquatic plants, which captured and imprisoned some of the salts. There is a beautiful water-snail in Lake Tanganyika, by name *Typhobia horei*, whose relatives live in the sea, and a fact like this shows us that some present-day fresh water animals may once have lived in the sea or had ancestors that lived in the sea. An interesting case is the presence of seals in Lake Baikal in Asia—a great lake far from the sea. Of course, seals are marine mammals, not fresh water mammals, but they live in Lake Baikal because it was once part of the sea or closely connected with it.

The Invasion of the Land.

In the Far East of the Indian Ocean, two hundred miles south of Java, there lies a small island called Christmas Island. It used to be a great haunt of birds, they say, for there are thick beds of phosphate salts, very valuable as fertilising manure, and these seem to have been due to the droppings of birds, accumulating for ages. The late Sir John Murray, one of the founders of the Science of the Sea (Oceanography), discovered the value of the island in the course of the *Challenger* Expedition (1873-1876), and the British Government was more than repaid for the whole cost of the expedition by the royalties obtained from the sale of the phosphates. The bird droppings, turned into rock, were carried away in ships to agricultural countries, and transformed to make food for growing corn and other plants; but why we wish to think of Christmas Island just now is because it is one of the homes of an extraordinary animal, the Robber-crab (*Birgus latro*), particularly interesting because it is one of the invaders of the dry land. It is a biggish animal, sometimes a foot long and six inches broad, more nearly related to hermit crabs than to ordinary crabs, but originally a marine animal beyond doubt. It must have an adventurous spirit, for it explores the island a long way from the shore, and it climbs the coco-palms for the sake of the nuts! After it has torn off the fibrous husk, out of which coco-nut matting is made, the Robber-crab hammers with its great claw at one of the dimples at one end of the nut. It breaks a hole through and, putting in one of its narrower legs, it spoons out the sweet milk. The Robber-crab gets its name because it is fond of coming near houses or workshops, and stealing things; sometimes it has been known to make off with an empty meat tin, using *that* as a protection for its tail!

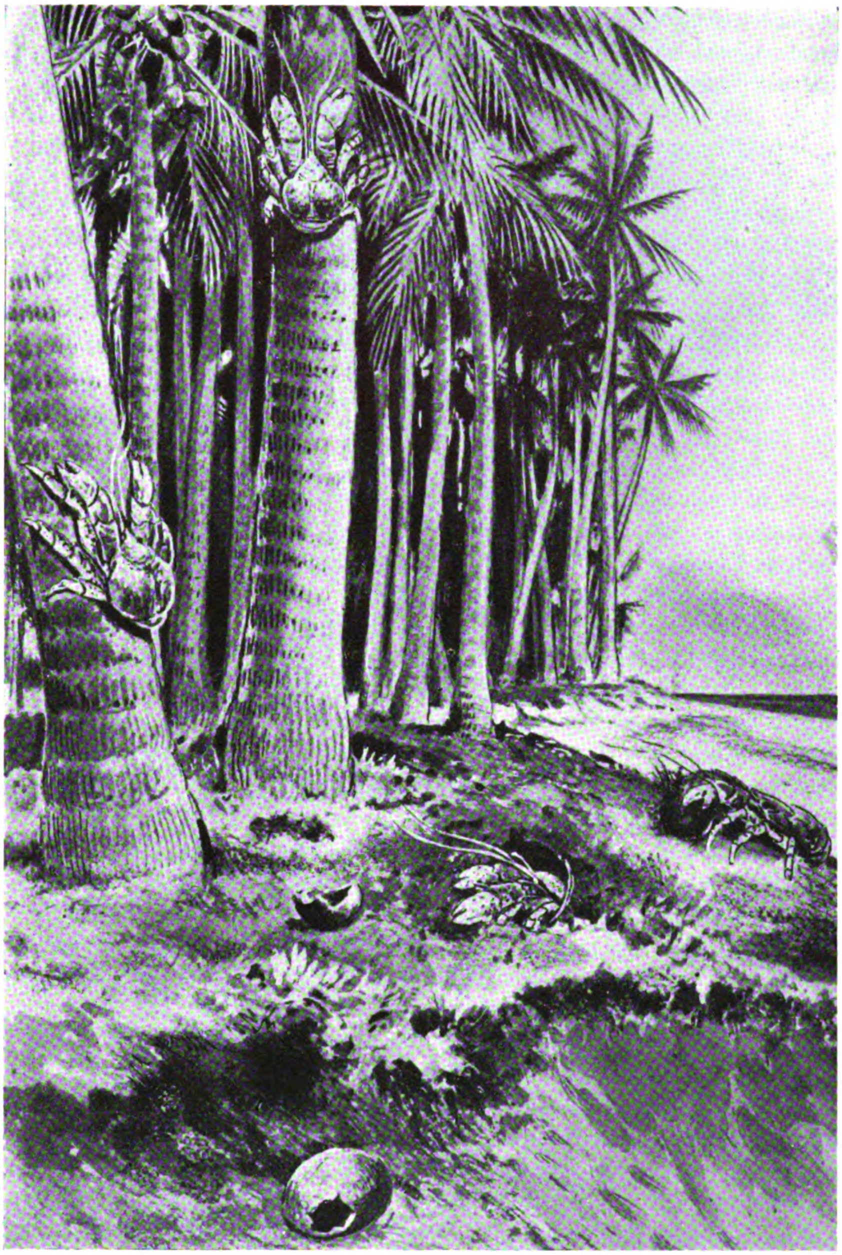
Most animals that live in water breathe by gills, as we see in lobsters and fishes, and these gills are feathery outgrowths inside which the blood is spread out so as to capture oxygen from the surrounding water. A gill is like a down-feather, or a country with a much indented coast line, in that it has *a large surface*, and as the water washes this there is abundant opportunity for the oxygen to diffuse in and for the waste carbonic acid to diffuse out. Breathing always means the intake of oxygen, and the getting rid of carbon dioxide ($+O$; $-CO_2$). Now the question arises: How a marine animal with gills can breathe dry air on land. For most land animals breathe by lungs, or something like lungs, hollow sacs *inside the body*, on the walls of which the blood is spread out. Now the Robber-crab still retains traces of gills, but on the wall of its gill-chamber there are numerous delicate projections which contain blood and absorb dry air. As regards its breathing, it is a betwixt-and-between animal.

Once a year the Robber-crab gives away its secret. It has to go back to the seashore to spawn. The eggs are liberated in the sea, and the young ones spend some time as free-swimming larvæ and then as creeping creatures on the shore. After they have grown strong they begin to explore the dry land. Long before that, however, the parents have scuttled back to their home among the coco-palms.

A very interesting point is that the coco-palm is not a native of Christmas Island, or of any of

these Eastern islands, where it has established itself in a sort of chance way, probably through the nuts being carried by ocean currents. It follows that the Robber-crab must have learned to climb the coco-trees and break off the nuts within *comparatively recent* times.

We have taken the Robber-crab as a sure and certain illustration of the way in which some animals have left the sea and invaded the dry land. It does not stand alone, for there are many land crabs in different corners of the earth—all requiring to go back to the water to start the next generation.



THE BIG ROBBER-CRAB (*Birgus latro*), THAT CLIMBS THE COCO-NUT PALM AND BREAKS OFF THE NUTS.

This relative of hermit-crabs occurs on islands in the Indian Ocean and Pacific, and is often found far above sea-level. The respiratory chamber is divided into two portions—an upper space with blood-vessels spread out on ridges and folds, and a lower portion with rudimentary gills. The larval stages live in the sea. The figure shows one of the robber-crabs emerging from its burrow, which is often lined with coco-nut fibre. The empty coco-nut shell is sometimes used by the Robber-crab for the protection of its tail, which is soft and full of oil.

If you turn over loosely-lying stones or break off big pieces of bark from a felled tree that is beginning to decay, you see squat wood-lice running quickly about. You will also find their "moults"—the dead husk (or cuticle) which is stripped off from time to time to let the animal grow bigger. If you take this "moult" on your hand, you will see that it is like a ghost of the living animal. It has been shed from the whole surface of the body, somewhat like a snake's "slough," and it shows the husk of all the limbs. If you try to count the limbs on the husk or on a dead wood-louse, using a pair of mounted needles to separate part from part on a piece of black paper, you will not count them right the first time! When you do count them right, the answer will be nineteen pairs. Why should this be interesting?—because almost all the lobsters, shrimps, and prawns have nineteen pairs; and the occurrence of the same number in the

wood-louse is one of the many proofs that this land animal has sprung from the marine sea-slaters (technically called Isopods). Some of these are often found between tide-marks, as if beginning the exploration which the wood-lice have finished.

But when we inquire further into the matter we find that there are a number of " slaters " living in fresh water, and this makes it probable that the terrestrial wood-lice were derived from a fresh water stock, which in turn had its ancestry on the seashore. In the same way it may be argued that the earthworms, which are among the most terrestrial of all animals (eating the earth as well as burrowing in it), sprang from a stock of fresh water worms, and it is interesting to remember that there are several earthworms, such as those called Alma and Dero, that have tiny gill-like outgrowths near the head end.

There were, in the course of ages, three great invasions of the dry land, and each of them had very important consequences. First, there was the *Worm Invasion*, leading on to the earthworms of to-day and resulting in the making of vegetable mould and fertile soil. Secondly, there was the *Centipede-Millipede-Insect-Spider* invasion —jointed-footed, air-breathing animals—the greatest result of which was the linking together of flowers and flower-visiting insects. Thirdly, there was the *Amphibian* invasion, starting probably from pioneer fresh water fishes. From the ancient Amphibians, with one foot in the water, so to speak, and the other on land, there sprang Reptiles, free from the water altogether, unless they went back to it on a new tack; and from the Reptiles there sprang both Birds and Mammals, so that the grand result of the third invasion was that it started the Higher Animals on their adventurous career.

There were minor invasions of the dry land, such as those led by Crustaceans, like the Wood-lice and the Robber-crab, or those led by certain Water-snails—the ancestors of our land snails and shell-less slugs. But the three great invasions were the Worm Invasion, the Insect Invasion, and the Amphibian Invasion, for they *made history*.

The dry land is a haunt that tests the mettle of an animal. For the freedom of movement is less than in the sea, so the movements must be nimble, or else there must be some cloak of defence or concealment. The changes of day and night, of summer and winter, are more felt than in the sea, so there must be something in the way of protection. There are risks of being dried up, of being blown away, of being buried alive, and so on, and we find among land animals a great many ways of avoiding these and other dangers. No sooner did animals get on to the land than they tried to get away from it ! Some became burrowers, like the earthworms ; some went up trees, like tree frogs ; some hid during the day and came out at night, like slugs.

The Conquest of the Air.

But the best and biggest change was to get into the air. And there have been in the course of the history of Living Creatures four great invasions of the air. First, there was the Insect invasion—leading on to our dragon flies and midges, butterflies and bees. Secondly, there was an invasion that was successful only for a time, that of the Flying Dragons or Pterosaurs, which varied from the size of sparrows to a span of fifteen feet. But they did not last. Thirdly, there was the Bird invasion, extraordinarily successful as everyone knows. And fourthly, there was the invasion of the air by Bats—mammals that can fly.

§ 3

THE PROGRESS OF LIFE

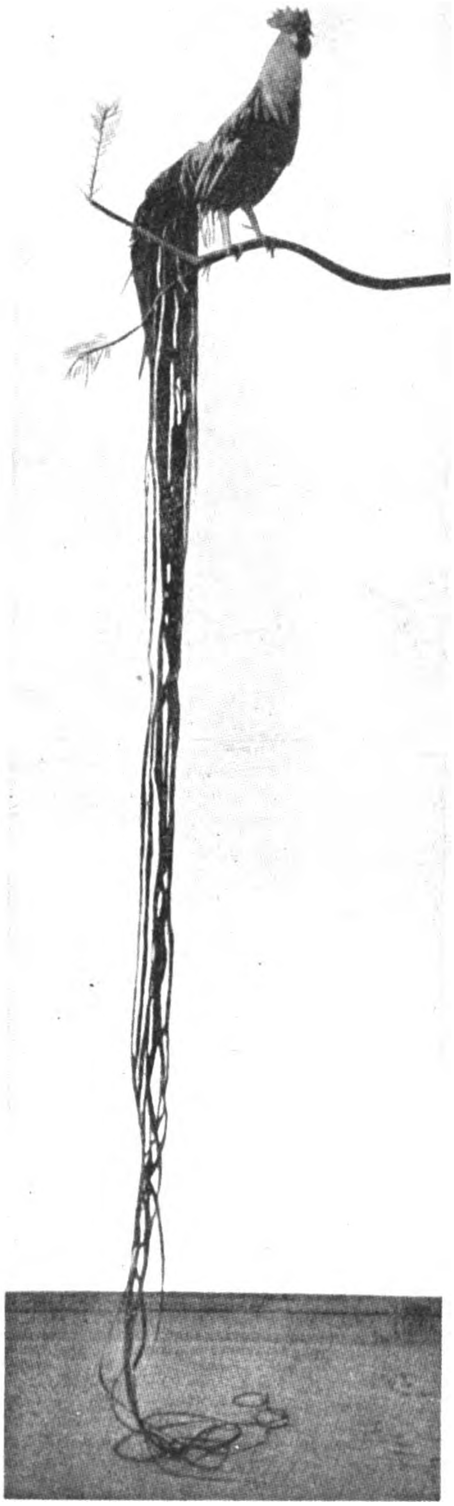
MILLIONS of years ago plants and animals had spread over earth and sea, and had established themselves in every possible place, except that there were no plants in the dark abysses of the ocean. But this peopling of earth and sea might have taken place without there being very marked progress towards fullness and freedom of life. In man's case we know that simple peoples spread over earth and sea in very ancient days before there was much in the way of civilisation. Both with living creatures and with men there were long ages of *possessing the earth* before the biggest strides of progress were taken. We have

pictured some of the changes in the world stage; let us think for a little of the changes in the actors and actresses.

In the "Arabian Nights" and similar old stories we read of the way in which a genie could change in a moment from one shape to another. What was a bird one moment was next moment a snake, at the next a fly, and again a grain of corn! Now during the millions of years since living creatures began to be upon the earth, there have been ceaseless changes from form to form, but differing from the genie's changes since they took place very slowly and were never magical. Nor was it that an individual plant or animal changed greatly—though that may happen when it is taken to new surroundings—it was rather that the children differed from their parents and from one another. We see these changes to-day when a hornless calf or a tailless kitten appears in a horned or tailed race, or when a white blackbird is hatched out, or when a black sheep is born, or when a copper beech suddenly appears, or a weeping willow, or a "wonder-horse" with its mane reaching the ground, or a pigeon with twice the usual number of feathers in its tail, or a Greater Celandine with its leaves all cut up, or a Chinese dog without hair, or a guinea-pig with an extra toe, and so on, and so on. Some plants and animals are much more changeful than others, and some are changeful for a while and then more stable; but the great fact is that from generation to generation novelties are always cropping up. The possessors of these novelties (called variations and mutations) are sifted in the struggle for life and endeavour after well-being, and the more advantageous succeed, whereas the less suitable are pruned off so that they leave no descendants or less than the usual number. Professor Punnett has calculated that if in a population of a thousand animals there arise at any time 10 per cent. of similar novelties with a 5 per cent. advantage in their favour, then in 100 generations, all the population will be like what once were novelties.

Changes Going on Still.

If we visit a dog show we see and hear an extraordinary assemblage—airedales, bloodhounds, collies, dachshunds, Esquimo-dogs, fox-terriers, greyhounds, and so on through most of the letters of the alphabet, but all of these are descendants of the wolf and the jackal, or one should say of various wolves and jackals. Novelties



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JAPANESE LONG-TAILED FOWL OR TOSA FOWL.

This extraordinary bird illustrates what may be called a physiological mutation. It is a true-breeding freak, with continuously growing tail-feathers. They may grow to be seven or eight feet long, and there are records of eighteen feet. The breed seems to be of very ancient origin. The offspring of a cross between a Tosa cock and a white Cochin Bantam hen were mostly Tosa-like, but the tail-feathers of the cock were not so long as usual.

cropped up from time to time—no one is very sure *how*—and man picked out those that pleased him most, and, keeping them apart, bred from them till he established race after race of domesticated dog. If man has done this in a comparatively short time, what may Nature not have done in a very long time, the struggle for existence doing automatically what man does deliberately—picking and choosing, pruning and sifting?

If we visit a pigeon show we see fantails, pouters, tumblers, jacobins, homers, barbs, and how many more, all descended from the wild Rock Dove, which still lingers in the seashore caves of Scotland and elsewhere. Man has established all these breeds out of the novelties supplied from the domesticated descendants of the Rock Dove. If he has been able to do so much in a short time, what may not Nature have done in the long time that has elapsed since the first bird appeared in the Jurassic ages—millions of years ago? The same sort of question arises in our mind when we look at all the different kinds of apples which man has been able to establish by taking advantage of the changefulness of the crab-tree by the wayside and of its descendants when the process of cultivation got going. Or think of the different kinds of cabbages—cauliflower, broccoli, Brussel sprouts, curly greens, and others—all derived from the wild sea-kale found growing on the seashore.

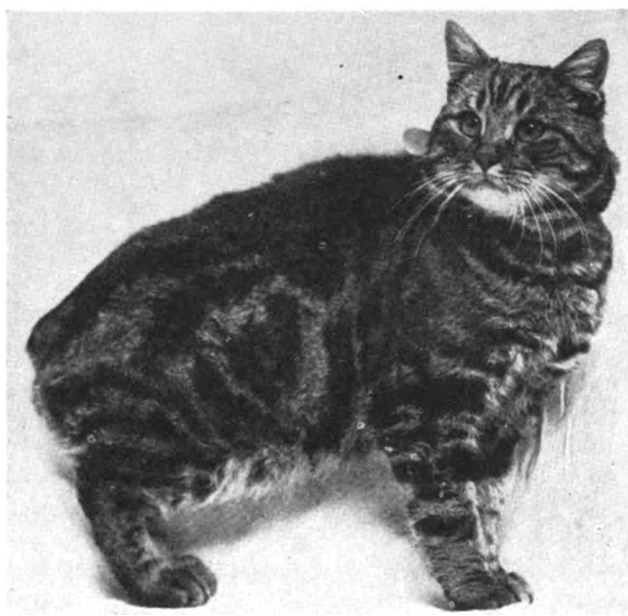


Photo: Sport and General.

MANX CAT.

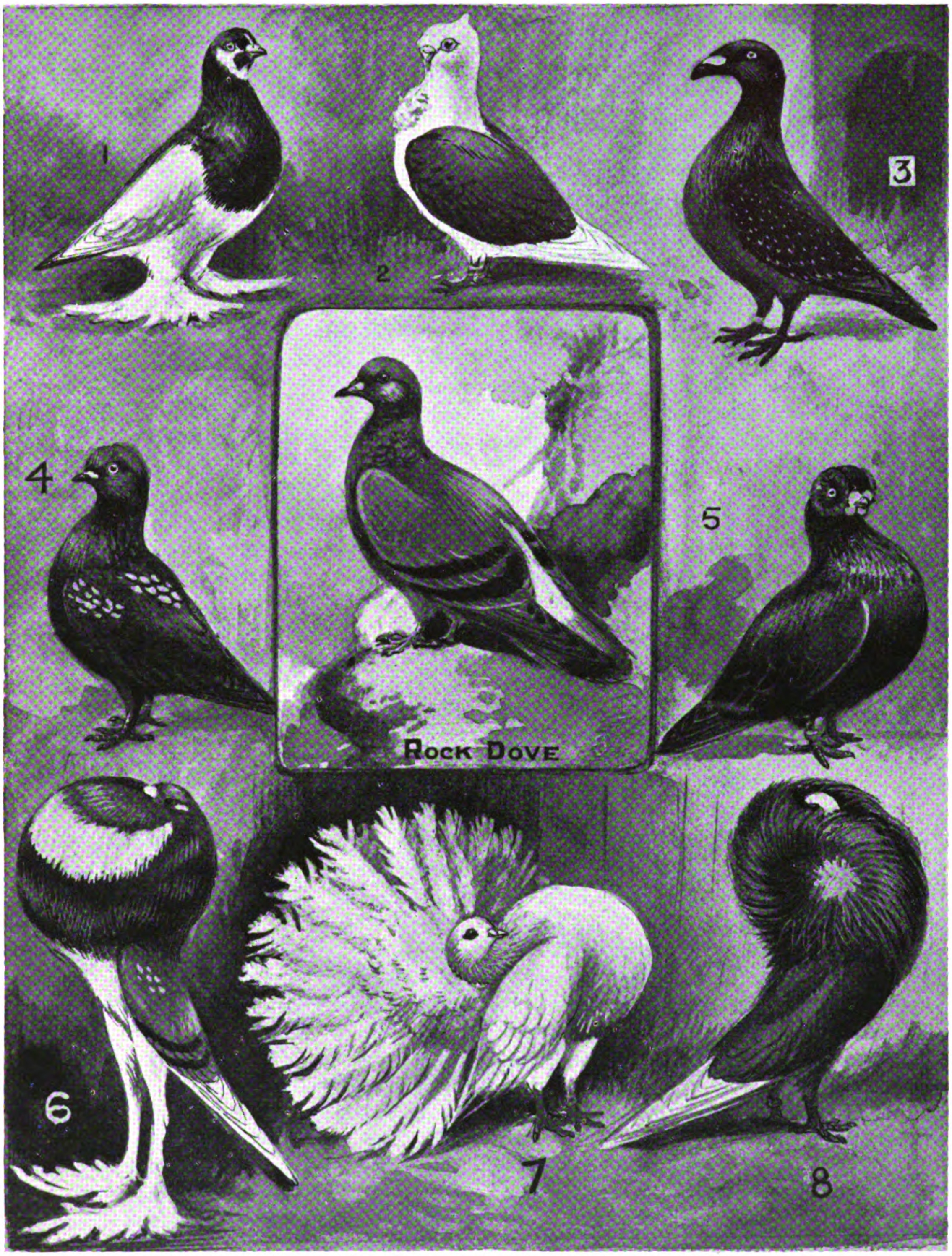
A variety of the ordinary domestic cat with a rudimentary tail. It is a native of the Isle of Man, and it illustrates what is meant by a discontinuous variation or mutation of the same nature as hornless cattle. When a Manx cat is crossed with a normal cat, the kittens are usually Manx-like.

The ancient crust of the earth was buckled up here and depressed there, so that continents and ocean-basins, highlands and lowlands were formed. But the raising of the crust meant weathering and the carrying away of mud, sand and gravel, which were deposited elsewhere, pressed and hardened into shales, sandstones and pudding-stones. So the earth got layer after layer, skin after skin, of second-hand rocks, and the oldest are on the whole lowest, though there were often strange tiltings and other disarrangements. In many of the rocks that had been formed from deposits on the floor of ancient seas and lakes, there are the remains of plants and animals that lived at the time, and it is from these *fossils* that we can read the past history of life with most security. The rock record is like a library on which all the oldest books were originally on the lowest shelves and the later books on successively higher shelves, with the modern books highest of all. Unfortunately, however, the shelves have been broken a good deal and there has been damage done by fire; moreover, a great many volumes are missing, so that most of the sets are incomplete. But in spite of all that, one can see in a general way how one literature has succeeded another as the centuries went past.

The Rock Record.

So it is with the fossil-bearing rocks. They cannot lie, but they require careful reading. What they show plainly is this, that for long ages, extending over many millions of years, the only animals were backboneless animals, such as sponges, corals, worms, sea-lilies, trilobites, and lamp-shells. Ages passed and fishes appeared, first gristly and then bony. More ages passed,

Great Steps in the Ascent of Animals.



RACES OF DOMESTIC PIGEON DESCENDED FROM THE ROCK DOVE (*Columba Livia*).

1. SADDLE TUMBLER: The Tumblers are strong in flight and those known as Flying Tumblers have a strange quality of tumbling backwards in the air. 2. BLACK TURBIT: The beak is very short; the feathers are divergent along the front of the neck and breast. 3. SHOW HOMER: Very intelligent pigeons, able to find their way home from great distances. 4. BLACK MOTTLE TUMBLER. 5. BARB: A heavy-wattled pigeon, with a curiously shaped bobbin-like head. 6. POUTER: A breed remarkable for the protruding globular crop. 7. FANTAIL: Well known for the backward tilted head and the outspread tail feathers which may be as many as forty, instead of the normal twelve. 8. JACOBIN: With exaggerated plumage on head and neck, forming a hood and a shoulder cape.

and in the time called the Old Red Sandstone Age there appeared the first Amphibians. The backboned animals had now found a foothold on land, but there was no hint as yet of anything higher than Amphibians, distantly related to our frogs and toads. Amphibians had a " golden age" in the Carboniferous Epoch, when the great coal-beds were formed from the débris of huge swampy forests of horse-tail and club-moss trees. And in the next epoch (the Permian) there emerged the first Reptiles. From some of these ancient reptiles, long since extinct, there evolved in later ages the Birds and the Mammals.

This, then, is what is meant by the Ascent of Life, that as age succeeded age, finer and more masterful animals appeared on the scene, animals with more freedom of behaviour, with quicker wits and deeper kindliness. All through the ages, life has been slowly creeping upwards, sometimes quickly leaping, " till at the last arose the man."

Ascent of Plants.

What is true of animals is true of plants also. For a long time the only plants were seaweeds and moulds (Algæ and Fungi). Then came the possession of the dry land, or rather the moist land, and there was a time (of which we have little fossil record) when there was a vegetation of simple plants, something like the liverworts and mosses of to-day. Ages passed, and the vegetation of the earth was mainly fern-like—consisting of a great variety of ferns and tree-ferns, horse-tails and club-mosses. Finally, out of a fern-like stock there arose the first seed-plants, and by and bye the true flowering plants, which form the greater part of the vegetation of to-day. It is a long and difficult story, but is enough just now to recognise clearly that in the plant world, as in the animal world, there was an age-long transformation, tending on the whole towards the appearance of finer and more beautiful living creatures. But we do not know that the mind, which shines out clearly among the higher animals, ever wakened up in the plant.

What is meant by "Higher."

" Puffing Billy " was the name given to one of Stephenson's early locomotives, so imperfect that when it met a cow it was a toss-up whether the mammal or the engine would give way. Now what are the great differences between " Puffing Billy " and a splendid railway engine of to-day ? There are two great differences. The modern locomotive is vastly more complicated, with ten parts for every one " Puffing Billy " had, and so is a bird vastly more complicated than an earthworm. In the second place, the modern locomotive is much more perfectly under control, it is more of a harmony, it is better knit together. So is a bird compared with a worm, and that is what we mean by " higher."

Among the simple animals are the Amœbæ, small specks that can be seen creeping in a flat glass dish if it is placed above a sheet of black paper. A hundredth of an inch in diameter is a common size, but many are smaller. There are several different kinds found creeping on the mud of ponds and ditches ; and there are two or three kinds that live in man, doing him no good. Each of these minute animals is quite complete in itself. It moves by rolling along in a sort of " tank "-like fashion, drawing in one part behind and protruding a corresponding part in front : it glides or rolls along. It can also feel. It can engulf smaller creatures and digest them ; it is sometimes a cannibal ; it takes in oxygen and gives out CO_2 ; it gets rid of waste products. It can grow bigger and it can multiply by dividing into two or into many. The point is that the Amœba has all the ordinary activities of a higher animal, yet it is only a hundredth of an inch in diameter and has no *organs* (like brain and heart and stomach) and no *tissues* like muscle (or flesh) and nerve.

We can understand a little of what the progress of life means if we compare an Amœba with a higher animal. The Amœba is a single cell ; it has no " body " in the strict sense ; it shows almost no division of labour ; it is like a one-roomed house. The higher animal is built up of millions of cells ; it has a complicated body with much division of labour ; it is like a house with a great many rooms for different purposes. Another great difference is that Amœbæ do not seem subject to natural death as higher animals are. They may be killed, but they do not die. They are so simple and they multiply so simply that they never get into arrears. Having no body to keep up, they make good their wear and tear quite perfectly. Natural death was the tax levied on acquiring a body.

What we have said may serve to indicate two of the great lines of progress among animals. On the one hand they became more intricate,

more *differentiated*, with more division of labour. On the other hand they became more controlled, more unified, more *integrated*—partly by the nervous system, partly by the binding of one member of the body to another, partly by the common medium of the blood, and partly by the chemical messengers or hormones which help greatly in the regulation of a harmonious life.

The Story of the Egg-eating Snake.

But another main line of progress was the establishment of adaptations, by which we mean particular adjustments of structure and function that make for efficiency in reference to particular needs or circumstances. Let us take the instance of the African snake called Dasypeltis, which feeds on eggs stolen from ground-nests. It has not very good teeth, and there are not many of them, but it is able to grasp the egg in its mouth. If it broke the egg-shell there it would certainly lose a good deal of the precious contents. It moves forward the right side of the lower jaw, holding the egg firm on the left. Then it grips with the right side and moves the left forward. So the egg passes to the back of the mouth, is seized by the muscular swallowing part (the *pharynx* in all animals), and begins to slide down the gullet still unbroken. Now, though it is almost incredible, there are sharp enamel-pointed teeth projecting through the roof of the gullet, and when the egg-shell is pressed against these it is neatly broken, and nothing is spilled out. The cracked egg-shell is then pushed out of the mouth, for Dasypeltis always returns the "empties"! What a series of fitnesses—the fixing teeth, the movements of the two sides of the lower jaw, the gripping part of the mouth, the elastic gullet, and the gullet teeth. And this is but a striking instance of what is true of all animals, and plants too, that they are bundles of fitnesses—special adjustments that "serve their purpose" well. But we must not pass on without thinking over these gullet teeth. How can there be teeth in a gullet? The answer is that these are prolonged downward-pointing processes from the underside of the backbone-bodies (or vertebræ) of the neck region. These processes are quite usual in backboned animals, but here they are long and sharp, and turned to a peculiar use in connection with a peculiar habit. *This is Nature's way.*

Freedom of Mind.

But another great line of progress among animals has undoubtedly been towards a greater fulness and freedom in the inner life of feeling, purpose and understanding, which we call "mind." As we have seen, the mind of an ant or a bee is very different from that of an ape or a bird, but there are common features—of enjoyment, of looking forward, of masterful control. The big fact of the ascent of life is that this inner aspect becomes more and more important. Life conquers things and mind guides life. The story of evolution is in no small degree the story of increasing freedom of mind. What is represented by flashes in the Amœba, dreams in the coral, glimpses in the ant becomes a more and more perfect day!

To sum up: Not only did living creatures possess every corner of the earth and sea, they became in the course of ages more complicated and more controlled, they gained fitness after fitness, and among animals there was an increased fulness and freedom of life, as the mind came to its own.

§ 4

FACTORS IN EVOLUTION

ORGANIC evolution is a process of becoming. Our fauna and flora are descended from an antecedent fauna and flora on the whole simpler; and so on back and back until we lose our clue in the thick mist of life's beginnings. Organic evolution was compared by Samuel Butler to a fugue, in which when the subject and counter-subject have been announced, there must thenceforth be nothing new, and yet all must be new; and, perhaps, we may name the subject and counter-subject of the long-drawn-out fugue of organic evolution as hunger and love. But while the evolution-concept states the general way in which Animate

Nature has come to be as it is—by a slow natural process of racial transformation—it does not as such disclose the factors at work in the sublime advancement (and the occasional retrogression) from age to age. That is the task of the causal theories of evolution which are still very young. The fact of evolution is recognised by all competent naturalists, but there is hesitation and confessed ignorance in regard to the factors. Partly through muddleheadedness and partly through intellectual dishonesty, the experts' frank admission of suspended judgment in regard to the factors in evolution has been twisted as if it implied hesitancy regarding the evolution idea in general. No competent naturalist has any such hesitancy.

Can we give any definition of Organic Evolution? This must be difficult, but we suggest the following. Organic evolution is a natural process of racial change in a definite direction (or in several definite directions in different parts) in the course of which new forms, with new adaptations and linkages, arise, take root, and flourish alongside of or in place of the originative stock. Organic evolution must be distinguished from *development*, which is the becoming of the individual—the beech-tree or the squirrel—from their respective egg-cells onwards. It should also be distinguished from *human history*, for man stands apart in his awareness of the past, in his power to control the future, and in his capacity for registering the gains of evolution outside the organism altogether, namely, in the social heritage. It would also be of advantage to have a different word for cases like the making of the solar system. Perhaps the word *genesis* would serve. For in the separation of the earth and the other planets from the parental sun there was nothing corresponding to the processes of elimination that are characteristic of organic evolution. The original matter-and-energy—we must hyphenate them now—of the nebular mass was differentiated into a solar system, but there was no sifting. Whereas it is characteristic of organic evolution that many of the organisms that shared in the struggle did not enter into the promises. There have been many lost races.

In the domain of things the processes that come nearest those of organic evolution are to be found in radio-active changes. Thus uranium passes through a succession of changes, resulting in the production of helium gas and a form of lead. This transmutation is in some ways like the transformation of species; but, nowadays, the chemico-physical clocks are all running down, whereas the vital clocks are more frequently winding themselves up. Progressive evolution, as in the pedigree of horse and elephant, is much more frequent and much more characteristic than retrogressive evolution, such as is illustrated in increasing adaptations to sedentary life or to parasitism. The creative syntheses achieved by the modern chemist are not unlike those of organic evolution, and we might especially compare them to the combinations effected by the Mendelian breeder or cultivator. But the difficulty is to find synthetic processes going on nowadays in the domain of things apart from man. In the realm of organisms, on the other hand, evolution proceeds apace. New departures are common; the Proteus still leaps; life continues to flow uphill.

When we try to get a picture of the sublime process of organic evolution, which has no doubt continued for several hundreds of millions of years, we receive certain great impressions. One is the multitudinous production of individualities; there are over a quarter of a million different kinds of living animals, each itself and no other. A second impression concerns the persistence with which every possible haunt of life has been and is being peopled—from sea to land, from earth to air. A third is centred in the establishment of fitness after fitness—often with a marvellous nuance of adaptation. And then there is the largest fact that in the course of ages, as life crept upwards, the mental aspect became increasingly manifest and masterful.

New Departures.

The central secret of life is the origin of the new, just as the central secret of the musician or the painter is his creativeness. Among the delightful birds called ruffs there are seldom two males alike. That is what is called *variability*. Each ruff is unique—itself and no other; and so is it with every child. "The very image of his father," "a living likeness of her mother," people say; but this is not very true to life! Attention is captured by some outstanding features that are indeed continued from parent

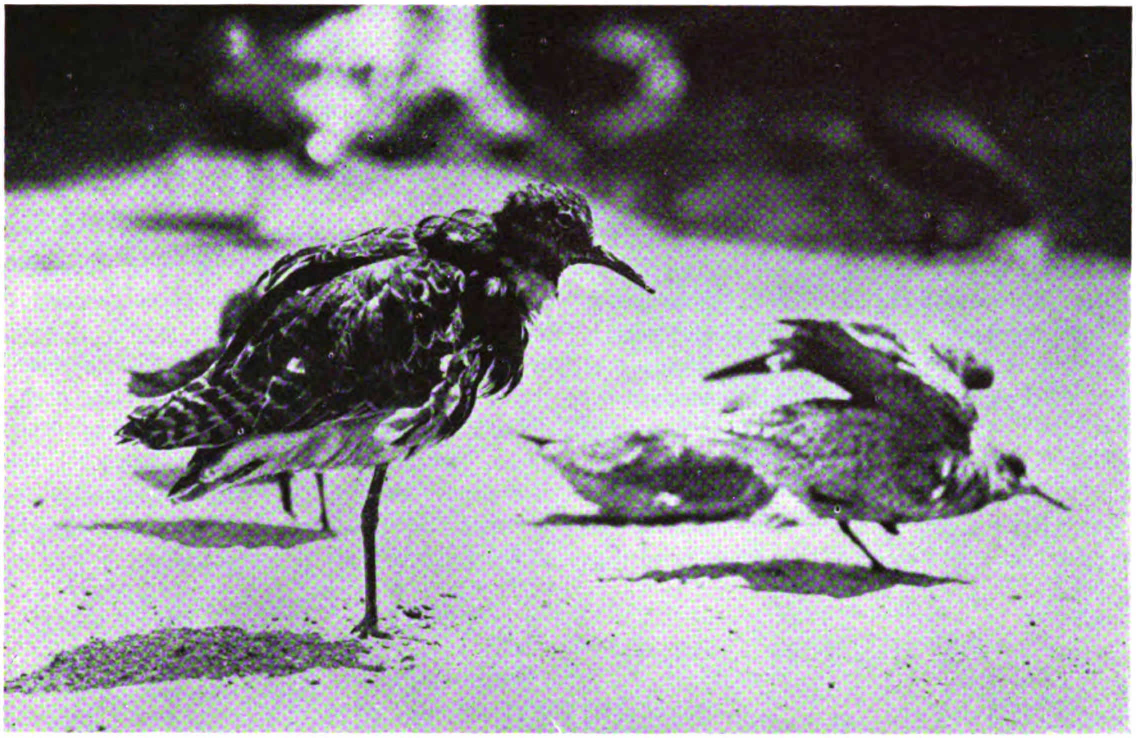


Photo: F. W. Bond.

THE RUFF (*Machetes pugnax*).

As regards colouring and markings the ruff in summer plumage is our most variable British bird. No two are quite alike. The female or reeve, on the other hand, does not vary much. At the courting time the ruffs make elaborate displays before the reeves, and the rival males make hustling rushes at one another, without much genuine fighting.

to child, but all the differences are left unnoticed. The proud parents are right: there is no child in the world like theirs. It may not be the strongest, the cleverest, the prettiest, the best behaved—but it is unique, unless, indeed, it has an identical twin. The differences among the members of a family are often extraordinary, and that is what is meant by variability.

We have already spoken of a visit to a pigeon show, with its fantails and pouters, jacobins and barbs, turbits and owls, carriers and runts, tumblers and trumpeters, and many more besides. In the Rock-Dove (*Columba livia*), which is still common on some of our shore cliffs, we find the fountain and origin of all our domestic breeds. So with the cochins and dorkings, hamburghs and andalusians, wyandottes and houdans, silkies and bantams, all have been derived from the Jungle Fowl (*Gallus bankiva*), still thriving in Indian forests. And what shall we say of the races of canary that have arisen since the sixteenth century, or of the varieties of cabbages and apples and wheats? Even when there has been a mixture of wild species, as in the pedigree of domesticated dogs and horses, we are still left wondering at the Protean changefulness of life.

What is so striking among domesticated animals and cultivated plants—where man covers with his shield many new departures that would be speedily destroyed in Wild Nature—is also true in natural conditions: the big fact, as Sir Francis Galton said, is organic flux. There are, no doubt, some very stable conservative types, like the Pearly Nautilus, that seem to have remained the same for millions of years, but whenever we begin to peer into a large number of specimens of almost any kind of living creature we are almost certain to find a crop of novelties. Whether we take the jellyfishes stranded on the shore or the different colours of eggs that cuckoos lay, the vertebræ of sloths or the teeth of apes, the shells of the dog-whelk or the markings of potato-beetles, the different forms of shepherd's purse or the colours of wild pansies, we are soon convinced that variation is as common among wild creatures as in conditions of domestication and cultivation.

But, as we have said, Nature is not so tolerant as man, and, in natural conditions, many tentatives are only born to die. It is plain, for instance, that Nature could never tolerate a pigeon with a bill so short that it could not break its way out of the eggshell. Many of man's pets in the dog line would make a rapid exit in Wild Nature.

It must not be supposed that all the differences that we observe between living creatures of the same kind have equal evolutionary value, for some of them are merely dints or imprints that are directly due to peculiarities in surroundings, food, and habits, while others are outcomes or expressions that are due to changes in the secret recesses of the germ-cells. As we are not certain that changes of the first kind can be handed on, it is to those of the second kind that we must look as furnishing the raw materials of evolution. To put it more technically, when we subtract from the total of " observed differences " all that can be reasonably regarded as " modifications," we are left with " variations " and these are the new departures that count.

It is very interesting to inspect the collection of a Lepidopterologist who " goes in for varieties." We ask to be shown the " currant moth," for instance, and the collector smiles a little, for he pulls out three drawers with scores and scores of different patterns. So it is in many other cases; it is the story of the ruffs over again, though we suspect that many of the collector's "varieties" are only transient "modifications" of no more evolutionary interest than ill-fed children with pale faces.

ENVOI

It is almost hopeless for us to think of the length of the ages during which life has been slowly creeping upwards. Years and centuries have little meaning when the whole story has taken hundreds of millions of years. We see the nearest star by the light that left it four years ago, but there are distant systems whose radiance takes 100,000 years to reach us. On such a grand scale has been the duration of life; and there may be very simple unprogressive microscopically minute organisms, living on the earth to-day, that began their existence a thousand million years ago. It has been calculated that if we could arrange a great cinema film of the evolution of living creatures, giving proportionate lengths to the successive geological periods and organic dynasties, arranging the whole so that it could be unrolled at uniform rate throughout a day, beginning at 9 a.m., then man would appear on the film just a few minutes before midnight! Yet man only among all living creatures is aware of the long drama, and even he has but a dim understanding of the plot.

But while naturalists are far from being clear as yet in regard to the factors in Organic Evolution, and while philosophers cannot clearly explain to us the glimpses they get of the Purpose of it all, there is no doubt as to the fact that there has been throughout the ages a long succession of achievements. Defeats, retrogressions, degenerations, parasitisms, blind alleys, there have been; yet on the whole Organic Evolution has been progressive. As age succeeded age, there has been an emergence of nobler and finer forms of life—an increase of feeling, perception, and control—in short, a growing emancipation of " Mind." This has its highest expression in Man at his best—with a personality growing in understanding, goodwill, and control. And this evolution is going on.

THE NEW NATURAL HISTORY

Third Volume

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ERRATA

p. 60. The elephant in the photograph is not pushing down a tree, but *pulling* to get free from bonds. When an elephant pushes down a tree it approaches it with head well up, and its trunk coiled and carried high. Placing the coiled trunk against the tree, it bears down with its head. When the stem has yielded sufficiently the elephant proceeds to press on the leaning tree with one of its fore-feet. All this is the result of careful training, but the photograph shows a recently captured elephant trying to make its escape, as also on p. 62.

p. 115. Woodpecker's nest. By inadvertence it was not noticed till too late that the photograph used was not that of a Green Woodpecker's nest, but a blackbird's in the stump of a birch tree. The eggs of the woodpecker are laid on wood-chips.

p. 166. Flight of Kittiwakes. In the caption to the photograph showing two kittiwakes in flight we have thrown doubt on the bird's ability to cross the Atlantic. But we find that this has been proved for a *marked* kittiwake. There are records also for two Black-headed Gulls, and for a third as far as the Azores. A Common Tern has been known to make the journey across the Atlantic, in an easterly direction, to Africa.

p. 167. Magnan's theory of flight, which he compared to the movement of a strong man using crutches. But an expert has been good enough to send us this forcible caveat: "M. Magnan should, however, try the experiment of proceeding on crutches across a floor of polished glass. He would then be able to judge how much his forward leaps were made possible by vertical downward thrust, and how much by the horizontal pull and push through the frictional resistance of the surface—a factor of which the counterpart in the air is negligible. It may be taken as physically axiomatic that the bird exerts a horizontal force sufficient to account for its observed (and very considerable) horizontal movement!"

p. 257. Squirrel's family. An unaccountable and regrettable aberration has occurred in regard to the number of journeys the squirrel may make in shifting her family. Perhaps we counted each journey twice—there and back! The records give one to six as the number of young squirrels in a litter, but the commonest number is two or three. The average of twenty litters, recorded by Mr. Barrett-Hamilton, from many parts of the British Islands, was three. In the southern parts of Britain there are often two litters in a summer. For "five to eight" read "several."

p. 985. Oysters. The first sentence of the third paragraph of "Animals and Man" should read, as the context shows, "When the month has an 'r' in its name, then we may eat oysters."

p. 1008. Wolf-dog crosses. Two experts have been kind enough to furnish us with circumstantially precise instances of fertile hybrids with wolf as sire and dog as dam.
One of these experts submits two cases of dogs aggressively attacking man.

p. 1083. By an unfortunate and inexplicable mistake a photograph of some sporangia or spore-making organs on the back of a fern-leaf was substituted for a photograph of the mallow's pollen. The caption for the photograph published should read: "A photograph of part of the back of a fern-frond showing some of the groups of spore-making organs or sporangia."

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NOTE.—Figures in italics refer to illustrations.

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